LIBRARY

SOUTHEASTERN MASSACHUSETTS UNIVERSITY
· UNITATE · 1895 · FORTIOR ·

LOWELL MACHERY

LOW COLLECTION

THE MANUFACTURE OF RUBBER GOODS.

CHARLES GRIFFIN & CO., LTD., PUBLISHERS.

FIFTH IMPRESSION. In Large 8vo. Cloth. With 4 Plates and Several Illustrations. 18s. net.

THE CHEMISTRY OF INDIA RUBBER.

A Treatise on the Nature of India Rubber, its Chemical and Physical Examination, and the Determination and Valuation of India Rubber Substitutes.

Including the Outlines of a Theory on Vulcanisation.

BY CARL OTTO WEBER, PH.D.

"Replete with scientific and also with technical interest. . . . The section on physical properties is a complete *résumé* of everything known on the subject."—*India-rubber Journal.*

SECOND EDITION. In Large 8vo. Cloth. With 800 pages and 154 Illustrations. 30s. net.

OILS, FATS, BUTTERS, AND WAXES:

Their Preparation and Properties, and Manufacture therefrom of Candles, Soaps, and other Products.

BY C. R. ALDER WRIGHT, D.Sc., F.R.S.,

Late Lecturer on Chemistry, St Mary's Hospital Medical School; Examiner in "Soap" to the City and Guilds of London Institute.

Thoroughly Revised, Enlarged, and in Part Rewritten.

BY C. AINSWORTH MITCHELL, B.A., F.I.C., F.C.S.

"Will be found ABSOLUTELY INDISPENSABLE."—*The Analyst.*

"Will rank as the STANDARD ENGLISH AUTHORITY on OILS and FATS for many years to come."—*Industries and Iron.*

SECOND EDITION. Thoroughly Revised. Illustrated. 16s. net.

THE CHEMISTRY OF MANUFACTURING PROCESSES.

BY BERTRAM BLOUNT, F.I.C., and A. G. BLOXAM, F.I.C.

"Certainly a GOOD and USEFUL BOOK, constituting a PRACTICAL GUIDE for students by affording a clear conception of the numerous processes as a whole."—*Chemical Trade Journal.*

In Large 8vo. Cloth. Profusely Illustrated. 36s. net.

A TREATISE ON

COLOUR MANUFACTURE.

A Guide to the Preparation, Examination, and Application of all the Pigment Colours in Practical Use.

BY GEORGE ZERR and DR R. RÜBENCAMP.

AUTHORISED ENGLISH TRANSLATION BY DR C. MAYER, OF BURGDORF.

"This comprehensive guide . . . useful and interesting."—*Oil and Colour Trades Journal.*

In Crown 8vo. Cloth. With Numerous Illustrations. 7s. 6d. net.

THE COTTON WEAVERS' HANDBOOK.

A Practical Guide to the Construction and Costing of Cotton Fabrics, with Studies in Design.

BY HENRY B. HEYLIN,

Of the Royal Technical Institute, Salford.

"Mr Heylin's text-book is a very reliable one. It is difficult to mark out any special points among so much excellent matter."—*Dyer and Calico Printer.*

LONDON: CHARLES GRIFFIN AND CO., LTD., EXETER ST., STRAND, W.C. 2.

THE MANUFACTURE OF RUBBER GOODS.

A PRACTICAL HANDBOOK
FOR THE USE OF MANUFACTURERS, CHEMISTS,
AND OTHERS.

BY

ADOLF HEIL AND DR W. ESCH.

ENGLISH EDITION BY

EDWARD W. LEWIS, A.C.G.I., F.C.S.,
CHEMIST TO MESSRS J. G. INGRAM AND SON, LONDON.

With Numerous Illustrations.

SECOND EDITION.

LONDON:
CHARLES GRIFFIN & COMPANY, LIMITED,
EXETER STREET, STRAND, W.C. 2.
1919.

[*All Rights Reserved.*]

TS 1890
H4

TS 1890
H4

PREFACE.

THE manufacture of rubber goods has grown to be so large an industry, and includes such a variety of detail, that it is surprising no comprehensive treatise on the subject has hitherto appeared. The late Dr C. O. Weber had promised a companion book to his standard work *The Chemistry of India Rubber*, but this was prevented by his lamented death. As soon as the German book, *Handbuch der Gummiwarenfabrikation*, by Drs Heil and Esch, appeared, the publishers of Dr Weber's book at once realised the utility of an English edition, and arranged to add it to their Technological Series.

The learned authors in their Preface indicate that their object was to provide a work treating in a connected way the various branches of the actual manufacture of rubber, or at least of such branches as are of general importance, so that specialists in rubber and others interested might have a complete treatise.

The book deals with the principles which apply to the manufacture of all rubber goods, and any advances which may have taken place since the publication of the original work have been solely in matters of detail, and do not lessen its value.

The English Editor has followed as closely as possible the original text and its arrangement, adapting it where necessary in regard to the machinery more generally in use in this country.

The subject being dealt with from the standpoint of the manipulation of raw rubber subsequent to its leaving the plantations, it has not been deemed necessary to discuss the very open question of plantation-grown rubber, although this is a matter of great importance, as upwards of a thousand tons were produced in the year 1907.

Thanks are tendered to several friends for kind assistance, especially to Messrs D. Bridge & Co. and F. Shaw & Co. of Manchester, for valuable drawings and other illustrations.

EDWARD W. LEWIS.

LOUGHTON, ESSEX.
Reprinted 1919.

CONTENTS.

INTRODUCTION.

PAGES

PLAN AND ARRANGEMENT OF A RUBBER-GOODS FACTORY . . 1–5

Boiler-house and Engine-room—Space-distribution generally.

CHAPTER I.

THE RAW MATERIAL 6–58

Brief Survey of Rubber-yielding plants, collection of the latex, and preparation from it of the Crude Rubber of Commerce—The Physical and Chemical Properties of Rubber—The Oxidation of Crude Rubber—Crude Rubber Storage—The Mechanical Purification of Crude Rubber—The Further Working-up of the Dried Rubber—The Mixing and Weighing Room—The Mixing Mills—The Calenders.

CHAPTER II.

THE VULCANISATION OF RUBBER 59–99

Early Methods—The Vulcanising Shop—The Press Shop—Plant for Sulphur-bath Vulcanisation—Consideration of the Vulcanisation of Proofed Fabrics by the Cold and Hot Processes—Results of J. Minder's Experiments on Cold Vulcanisation.

CHAPTER III.

THE MIXINGS 100–119

Preparation of Golden Sulphide—Manufacture of Substitutes—Treatment of Besk for use in Rubber Mixings—Asphaltum and Pitch as Ingredients of Mixings—Fats, Oils, Paraffin and other Waxes in Rubber Mixings.

CHAPTER IV.

THE MANUFACTURE OF SOFT-RUBBER ARTICLES. . . . 120–200

The Manufacture of Hose: (*a*) Vacuum and Pressure Hose, with and without Insertion, for Conveying Purposes; (*b*) High-pressure Hose (hose with braided insertion of hemp cotton or brass-wire); (*c*) Manufacture of "Spiral" Hose; (*d*) Canvas Hose with Rubber Lining—Moulded

PAGES

Goods, and Hollow articles such as Balls and Toys—Seamless Tubing and Shaped Cord—Preparation of Sheet for "Mechanicals"—Press-cured Goods—Rubber Belting—Rubber Rollers—Pneumatic Inner Tubes and Tyres, Pedal and Brake Rubbers and Cab Tyres—Soft-rubber Surgical Goods, etc.—Enamelling Bands and Rings—Rubber Stamps—Waterproof Cloth—Imitation Leather Cloth—"Cut-sheet" Rubber Shoes—Insulated Wires and Cables—Compositions of Asbestos and Rubber—Eraser Rubber—Para Sheet and Elastic Thread.

CHAPTER V.

MANUFACTURE OF EBONITE 201–224

Preparation of Ebonite Dust—The Ebonite Mixing—Manufacture of Tinfoil—Ebonite Rods and Tubes—Insulation Tubes—Ebonite Accumulator Cases—Moulded Ebonite Goods—Buffing and Polishing Ebonite—Ebonite "Mechanicals"—Imitation Ebonite—Moulding and Pressing Imitation Ebonite Goods.

APPENDIX I.—THE REGENERATION OR RECLAIMING OF RUBBER WASTE AS CARRIED OUT IN RUBBER FACTORIES . . 225–229

APPENDIX II.—SPECIFIC GRAVITY 230–231

INDEX 232–237

RUBBER MANUFACTURE.

INTRODUCTION.

In accordance with the general scheme of this work, the scientific and theoretical portions have been purposely limited to what was absolutely necessary and essential, for the little that is known with scientific exactitude about rubber must still be looked upon as more or less fragmentary. The book, therefore, begins with a description of a convenient factory and plant, theoretical questions being generally dealt with in connection with the practical matters on which they bear, an arrangement which is likely to facilitate reference.

PLAN AND ARRANGEMENT OF A RUBBER-GOODS FACTORY.

In whatever sphere of industry a new enterprise be initiated it is essential, in these progressive times, that the fullest possible use be made of every real advance that has taken place and of every substantial improvement brought about within that sphere. The rubber industry is pre-eminently of that class which demands the greatest possible degree of perfection in mechanical equipment, if the universal competition of to-day is to be successfully met, and at the same time a first-class product is to be put on the market. As everyone interested in the matter is aware, the success of any given class of rubber goods is largely a matter of confidence on the part of the buyer, and a new product can only make its way side by side with others already known if it offers some advantages to buyers. The only way, however, in which it becomes possible to offer such advantages, without detriment to profits, is by so adjusting plant and equipment as to reduce the wages bill to a minimum, by the adoption of economical methods of manufacture, and by avoiding waste. In the first place, the buildings should be so arranged that the separate workshops, in which the different stages in the process of manufacture are carried through, are continuous with

one another. Extensive subdivision is not desirable. The different branches of manufacture cannot well be separated from one another without interfering with the possibility of general supervision. A further very important point is with reference to the dust which is produced during certain operations, and which is scattered about the shop. In all processes of "making-up" rubber goods it is most important to exclude, as far as possible, every trace of dust, in order

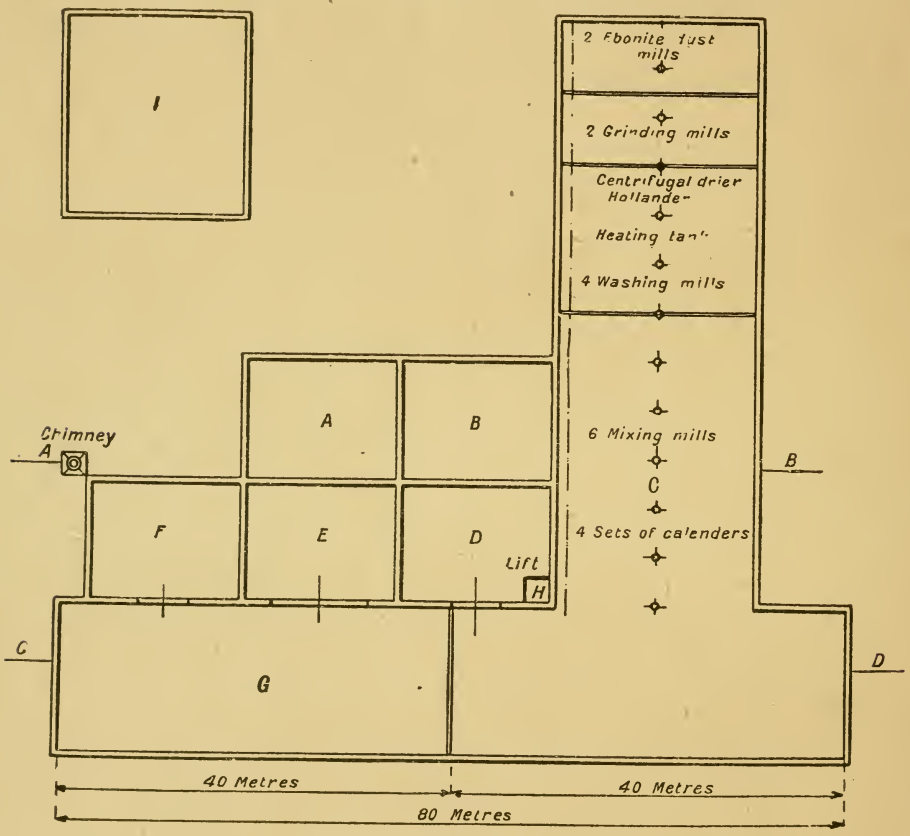


FIG. 1.

to produce a thoroughly sound and serviceable article. An air-cushion, for example, is of no use whatever if it develop leaky seams, owing to particles of dust settling on the solutioned edges of the rubber sheet while the article is being made up. On this account a building with an upper floor is to be recommended, so that all those branches of manufacture which must be kept free from dust can be put into separate isolated shops. There still exist many works which are arranged in just such a primitive fashion

as would serve the purpose of a smithy. One of the principal sources of trouble arises from the roughness of the walls, on which the dust settles, only to be disturbed by the slightest draught, settling again on fabrics and rubber.

The engines and boilers should occupy a central position, and the vulcanising plant should be situated close to the boiler-house. The mills, again, should be near the engine by which they are driven, so that the main shaft with which they gear may be driven direct. In selecting the machinery for the works, one's chief care should be to procure only such machines as will, by their use, lead to economy in labour. The advantages of particular machines will be indicated when dealing

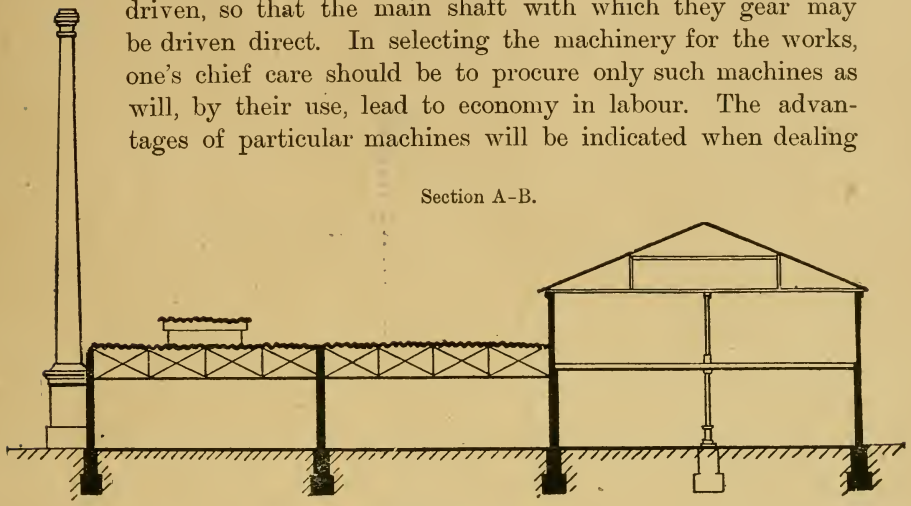


FIG. 2, A.

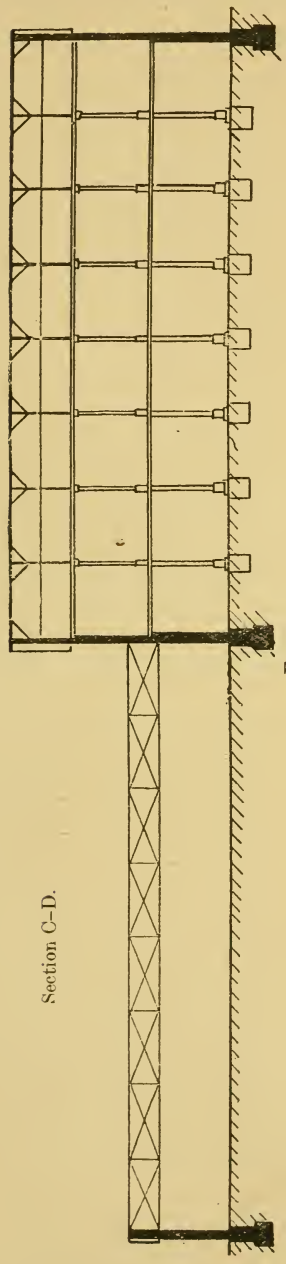
with the separate branches of manufacture, and sundry faults in construction will also be referred to.

Fig. 1 shows the ground-plan of a factory, fig. 2, A and B, sectional elevations, and with the help of these the reader will be able to form a clear mental picture from the following description. The logical method in explaining the ground-plan is to begin with the steam-production, or with the motive power, and to follow this up with descriptions of the shops in the order in which they are concerned in the actual processes of manufacture. In accordance with the manufacturing sequence, theoretical chapters on vulcanisation and mixings are inserted after that which deals with the raw material.

Boiler-house and Engine-room, and Space-distribution generally.—The buildings marked A and B in fig. 1 serve to house the boilers and engines for the production of steam and power, and of electric energy for lighting purposes. Each of these separate buildings is 7 metres high, and is covered with a span roof of girder-work.

Building A contains the Cornish boilers, of about 100 square

metres heating-surface, and the superheater. Steam for the engines is generated in two boilers working at 180 lbs. pressure, whilst the other boilers, working at 150 lbs., provide the steam required for vulcanisation. The use of fire-tube boilers is certainly much more rational in a rubber factory than that of water-tube boilers, because in the case of the former the great consumption of steam which takes place in the vulcanising processes, through the continual opening and closing of the vulcanising apparatus, can be more readily compensated than in the case of the latter, the steam-space of the fire-tube boiler being by far the greater. With water-tube boilers, on the other hand, in spite of their greater heating surface, the irregular steam-consumption results in much water being carried over, a circumstance which, in the first place, is opposed to economical working, and, secondly, may be detrimental to the goods undergoing vulcanisation; we shall make special reference to this point again later on. The boiler-house is so arranged that it can be enlarged without difficulty, so that additional boilers may be conveniently introduced at any time. Great value is to be attached to the superheater, so that dry steam can always be used in the vulcanising heaters. Besides the boilers there are also in this building the feed-pumps, the water-softener, and the oil-separator for condensed steam.



Section C–D.

FIG. 2, B.

The engine-room B, fig. 1, like the boiler-house, of which it is in a sense a continuation, is 7 metres high by 15 metres wide; its length is 12 metres. The triple-expansion engine housed in it drives the main shaft of the machine-room C (rope drive), together with a 100-H.P. generator used for driving the machinery in other

rooms. A generator for lighting purposes, together with a battery of accumulators, is also situated in the engine-room.

The storeyed building C adjoins the engine-room B and the vulcanising shop D. In this building are contained the mills and various other machines, which are arranged in sets. The mixing mills and calenders are not enclosed in any way, but the spaces containing the washing plant, the grinding and waste mills, are separated by means of glazed partitions. Adjoining these is the plant for the preparation of substitutes and surrogates, followed by the sheet-cutting shop, and finally by the mixing-room and store for the batches of mixed rubber.

In the room C, which is not subdivided, and which is the machine-room proper, places are found for the following, in addition to the mills and calenders: all lathes and drills as well as tube machines and other heavy machinery for the "mechanical department," with the exception of machines for making hose and tubing with insertion.

The hose shop and the "mechanicals" department are in the building G, which runs along the ends of C, D, E and F. The hose shop, 40 metres long, is constructed with a span roof 15 metres wide, and adjoins a storeyed building. The hose shop should be built on the ground-level with a span roof so that the hose-mandrels can be manipulated in it without difficulty. The vulcanising shop, which is subdivided into three compartments, is situated, as already pointed out, next to the boiler-house, in order to avoid having to carry the steam an unnecessary distance to the heaters. Compartment D contains the vulcanising "pipes" (autoclaves), while the presses are in compartment F. Between these two rooms is room E, which is used as a moulding shop.

The rooms on the upper floor are used for making up sundry articles, such as balls, surgical goods, ebonite goods, waterproof goods, etc. They are in direct communication with the vulcanising shop by means of the lift H.

The spreading-machines and also the ebonite-dust plant are located in a separate building I. The office buildings adjoin the factory buildings G.

CHAPTER I.

THE RAW MATERIAL.

Brief survey of Rubber-yielding plants, collection of the latex, and preparation from it of the crude Rubber of Commerce.—Considering the great importance of repairing as far as possible the damage done by the ruthless destruction of rubber trees in the process of rubber-collection—a point which has for years been repeatedly insisted on by the technical press—one might have supposed that these plants would long ago have been most carefully studied in every aspect, and have become really well known. Actually, however, our knowledge of even the most important of the rubber-yielding plants is, as E. de Wildeman[1] has recently pointed out, still extremely meagre, despite the efforts put forth by zealous workers. The object aimed at in the following pages is to present to the man technically interested in rubber, a condensed general survey of the methods of collecting the various commercial sorts of crude rubber, so far as our knowledge extends at the moment.

The rubber of commerce comes partly from the northern parts of South America and from Central America, partly from Africa and Madagascar, partly also from India and the neighbouring islands, as well as from Polynesia.

At the present time the most important kind of commercial rubber, and, broadly speaking, the best, is Para,[2] which takes its name from the capital of the Brazilian province of Para. Para is obtained essentially from the latex of plants of the genus *Hevea*, of which numerous species are indigenous to South America. About thirteen of these species have so far been identified. *Hevea braziliensis* (Müller, Arg.) is at present the chief source of the rubber;

[1] "Caoutchoutiers de l'Amazonie" (*Le Caoutchouc et la Gutta-percha*, 1905, ii. 129).

[2] Pronounced Parà.

this species is found, according to E. Ule's investigations, principally in the southerly portions of the country watered by the Amazon and its tributaries. According to more recent observations, however, other species than those of *Hevea* contribute to the supply of latex from which Para is prepared, and the *Hevea* latex is occasionally worked up in admixture with that from species of *Sapium*; for example, the *Tapuru, Murupita,* and *Siringorana.* According to Franz Clouth[1] *Micranda siphonoides* also contributes to the production of Para, but information from other sources is to the effect that, in spite of the wide distribution of *M. siphonoides,* its latex is little used, for the sap is bitter and cannot be worked up with *Hevea* latices. Moreover, the natives do not trouble to work up *Micranda* latex by itself.[2] It must certainly be admitted that the mixing together of different latices is not altogether desirable in the interests of the quality of commercial "Para." Commercial Para is produced not only in the Brazilian portions of the country watered by the Amazon, but also in Bolivia and in certain parts of Peru. Bolivian Para in particular is recognised everywhere as being of excellent quality. This may be largely due to the fact that the districts from which Bolivian Para is derived are so extraordinarily rich in *Hevea* trees of more than a hundred years old, it being generally accepted that the latex from such trees is superior both in quantity and quality to that obtained from relatively young trees. On the other hand, the conditions of transport are such that Bolivian Para invariably comes on to the market in a well-matured condition.

The collection of Para rubber in the above-named districts of South America is carried out as follows. A contractor leases a stretch of forest of convenient size from the Government, and fits out gangs of labourers with tools and provisions. To each group of labourers a district is allotted, containing about 100 to 150 rubber trees. Footpaths having been made through the forest to the separate trees, the tapping operation begins. With the aid of a *machado,* a short-handled hatchet of American manufacture which has now been generally introduced, incisions are made in the bark of the tree to such a depth that, although the laticiferous vessels are laid open, the vitality of the tree is not affected by numerous incisions. This operation commences at daybreak. Beneath each incision is fixed a small collecting vessel to catch the latex which trickles out. About three hours after tapping, the cuts become

[1] *Gummi, Guttapercha, und Balata,* Leipzig, 1899, p. 74.

[2] E. de Wildeman, *Le Caoutchouc et la Gutta-percha,* 1905, ii. 171.

sealed up again, and the latex which has flowed out is transferred to larger vessels, *calabashes*. The cuts are reopened in the evening, and yield still further quantities of latex. After about a week fresh incisions are made, and the collecting process just described is gone through again. A district (*estrada*) of 150 trees yields on an average about forty-five litres of latex at each tapping. Assuming that the whole collecting season includes twenty tappings, one *estrada* will yield on an average about 900 litres of latex, from which about 400 kilos. of crude Para containing a normal percentage of moisture will be obtained. The latex is taken in the calabashes to the storage place, and is there worked up to rubber in the following way:—The latex is poured into flat dishes, from which it is scooped out and poured over a thick stick, supported at one end on a rough wooden framework, the stick with the adherent latex being then rotated by the hands while it is held in the smoke from a fire. The formation of a thin pellicle of rubber round the stick is brought about partly by the heat of the fire, and partly by the action of the chemical compounds contained in the smoke, and over this pellicle more latex is poured, the smoking process being repeated. By the repetition of this operation a ball of rubber is gradually built up, consisting of innumerable superimposed thin pellicles.

Fig. 3.

In some districts special virtues are ascribed to the smoke of a fire fed with nuts of the urucuri or tucuma palm. Containing as they do some 12 to 15 per cent. of moisture, the balls of rubber are of a more or less yellowish-white colour inside, frequently streaked with lines of a darker colour, representing bands of lower moisture-content, and surrounded by a dark, relatively dry, outside layer. Some of these balls of rubber come on to the market without any further sorting; some are first cut open and sorted by experts at the ports of Manaos and Para. On cutting the balls open a number are usually discovered in which the smoking process has not followed the normal course, and which contain patches of spongy lacunæ containing serum; such balls are designated "Entre-

fine" and not "Fine" Para. Both Fine and Entrefine Para have a pleasant, smoky, ham-like smell. A further distinction is made between *hard-cure* and *soft-cure* Fine Para; this, however, is not accompanied by any appreciable difference in price. As to when a Para may be designated *hard-cure* and when *soft-cure*, that is a point that still requires clearing up. Disputes between buyer and seller on the point are not infrequent; hitherto they have generally ended in favour of the seller, but there is little doubt that if some

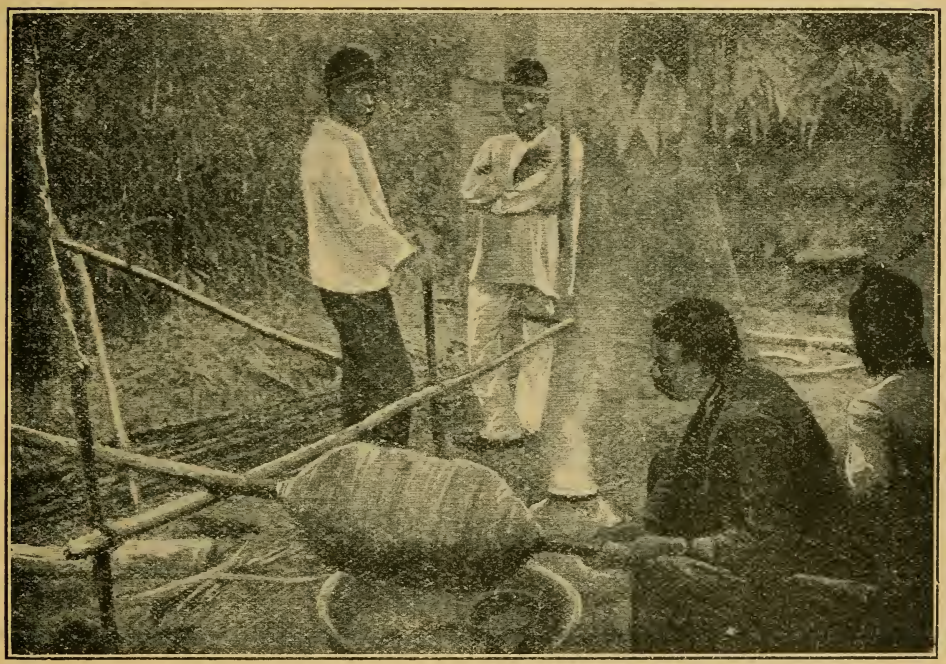


Fig. 4.

generally recognised system of classification could be agreed upon, the outcome of such disputes would be different. Finally, only about 70 per cent. of the latex collected from *Hevea*, etc., is converted into smoked Para. The remaining 30 per cent. cannot be smoked, either because rubber has already separated from it spontaneously in the various receptacles, or because the latex has coagulated while flowing from the tree-trunk. The rubber obtained in this way is merely pressed together into masses, which acquire a dark outward appearance owing to superficial drying, and come on to the market packed in casks as Negroheads, Sernamby, and, in the case of certain kinds, as Cametas. According to the latest accounts,

Cametas in particular are derived from rubber-trees which have become so badly scarred that it is no longer possible to extract the latex in such a way that it can be smoked. The product obtained in this way not only contains more water, but is a good deal more impure than smoked Para, owing to its having coagulated on the tree. In addition to particles of bark, sand is also an objectionable impurity in these unsmoked kinds of *Hevea* rubber. Still, when they

Fig. 5.

have been carefully cleansed, even these lower grades of rubber are very useful.

A peculiar kind of *Hevea* rubber is "Mattogrosso Para" or "Virgin Para" (not to be confused with the similar, but more impure, "Virgin Sheets"). It is probable that this rubber is derived from several species of *Hevea*; it is separated from the latex by the addition of alum or other substances, and comes on the market in large loaves with a pronounced cheese-like smell. "Virgin Para" gives a very light-coloured rubber when washed, and vulcanises quite as readily as ordinary Para. Unfortunately

"Virgin Para" has, as a rule, the drawback of containing the hard scales of beetles which have crawled into the rubber during the coagulating process, and these cause endless difficulty in the cleansing operations. Frequently they simply cannot be removed, and the use of Virgin Para for certain purposes must for this reason be, in general, excluded.

Fortunately, marked success has attended the efforts made to grow the valuable Brazilian *Hevea* in plantations, and to cultivate it instead of the unsuitable indigenous rubber-plants in Africa and Asia. The plantations in Ceylon and the Malay Peninsula already play some part in the actual production of rubber. On the plantations, however, the rubber is not as a rule prepared from the latex by smoking, but is separated by mechanical means. In order to prevent premature coagulation of the rubber the vessels are partly filled with water before use. The collected latex is filtered through sieves, before undergoing further treatment, and is then allowed to stand until the rubber-yielding substance has separated as a cream on the surface. The cream is freed from the greater part of its occluded water by a gradually increasing pressure, and is then rolled or pressed into thin sheets, which are converted by slow, carefully controlled drying into the wonderfully pure product which is now known and valued under the name of "Ceylon Para." It has now, however, become the general practice to wash and dry the product on the plantations, by methods similar to those in use in rubber-goods factories. However, the last word on the preparation of rubber on the plantations has not yet been said. In comparing the plantation Para produced so far, with South American Para, it must, of course, not be forgotten that there are no 150-year old Heveas to deal with as yet on the plantations, as there are in the Amazon district. The speed of vulcanisation of plantation Para is the same as that of ordinary Para.

The Brazilian province of Ceara also produces, from its dry stony soil, a rubber-tree—the *Manihot Glaziovii*—belonging, like the Heveas, to the *Euphorbia* family. Rubber is obtained from the Manihot by making an incision in the bark, and allowing the latex to flow out and to coagulate without attention, partly on the tree itself, and partly on the ground. When the rubber is scraped up together, it is unavoidable that it should be badly contaminated with fragments of bark and particles of sand. Despite the presence of these impurities, Ceara rubber, which is also called in the trade Maniçoba (pr. Manissōba), after the Portuguese name for the *Manihot*, is a good, strong rubber, very useful for many purposes.

Its resin-content is very little higher than that of Para, and its speed of vulcanisation is very nearly as great. The inorganic constituents are relatively high in Ceara, the high percentage of magnesia being, apparently, characteristic of this kind of rubber.

The rubber from *Hancornia speciosa*, also a Brazilian product, is of very much lower value than *Hevea* and *Manihot* rubbers. The *Hancornia* grows in the provinces of S. Paulo, Bahia, Pernambuco, and Maranhao. Coagulation is effected by adding alum or sea-salt to the latex, or even by merely allowing it to stand until the rubber-cream separates. The cream is lightly squeezed and dried, but still retains a considerable quantity of water. In the trade the rubber obtained from the *Hancornia* bears the general name of "Mangabeira," but latterly one has come across more precise names such as Santos Sheets, Rio Sheets, Pernambuco-Mangabeira, etc. This *Hancornia* rubber is generally of a pale pink colour, and has a strong smell of Moselle wine. One particular sort only, Mattogrosso-Mangabeira, which has been on the market for some time, is almost white in colour, with the same wine-like smell. Mangabeira rubber contains about 6 to 12 per cent. of resins, and differs from Para and Ceara in exhibiting a marked sluggishness in vulcanisation, which necessitates the employment of higher proportions of sulphur and higher vulcanising temperatures.

Formerly opinions differed very widely as to the tree from which the so-called "Caucho" or "Peruvian ball" of commerce is derived. On the one hand, it was assumed that Caucho was yielded by *Hevea*, *Cameraria latifolia* and *Hancornia speciosa*,[1] whilst Henriques[2] brought forward grounds on which he himself doubted whether either *Hancornia* or *Castilloa*, which had been mentioned by others as a source of Caucho, occurred on the eastern slopes of the Andes at all. The present position is that Dr. Ule's recent journey of investigation has shown that on the one hand *Hancornia speciosa* does actually occur on the eastern slopes of the Andes, and is much more widely distributed than had been hitherto supposed, but that, on the other hand, Caucho is derived from a species of *Castilloa*, viz., *Castilloa Ulei-Warburg*.[3] This fact explains the great similarity between "Peruvian" and "Ecuador balls" and "slabs," of which latter the source was long ago shown

[1] See Franz Clouth, *Rubber, Gutta-percha, and Balata*, Leipzig, 1899, p. 78. Translation, London, 1903, p. 90.

[2] *Der Kautschuk und seine Quellen.* Dresden, 1899, p. 13.

[3] *Gummi-Zeitung*, 1905, xix. p. 962.

to be a species of *Castilloa*. The similarity spoken of is not limited to external characteristics, but extends to the chemical composition and the speed of vulcanisation of the rubber. The only surprising thing is that, according to statements which formerly were frequently made, the Caucho-Castilloa cannot stand even careful tapping, but is completely destroyed by it, this being proffered as an excuse for felling the Caucho trees, a usual practice in Peru and Western Brazil, whereas *Castilloa elastica* stands tapping very well, and is tapped in plantation-fashion over a considerable area in South and Central America. The latex of the Caucho tree is mixed with the sap of the *Sachacamote*, or with soapy water; the clots which separate are partly freed from water and pressed together, the balls so obtained being bound round with strips of raw rubber, thus giving to the Caucho of commerce its characteristic outward appearance. It is asserted that cutting down the Caucho trees would not necessarily lead to their extermination, since the stump would very rapidly throw up shoots, develop new branches, and in a few years in the place of one felled tree a group of trees would be found.[1] In spite of its abominable smell and the dirt which it contains, and from which it is not easily freed, Caucho is a very valuable rubber. Its resin-content is low, its speed of vulcanisation only slightly less than that of Para sorts. In contradistinction to the latter and to Ceara, Caucho is very dark in colour, after normal vulcanisation to the stage of soft vulcanised rubber.

Castilloa elastica, mentioned above, with its numerous varieties, is found growing wild in all parts of Central America, and as far south as Peru in South America, and is already being extensively cultivated. When carefully prepared the rubber obtained from *Castilloa* is of quite a superior quality, containing little resin, light in colour, not unpleasant in smell, and having a high speed of vulcanisation. Unfortunately the methods of dealing with *Castilloa* latex are generally still so crude and uncleanly that the rubber produced for the most part lacks the good qualities which originally belonged to it. The amount of *Castilloa* rubber which comes on to the market, under the names West Indian, Ecuador, Guayaquil, Centrals, etc., is very considerable. It is to be hoped that the example of the planters in Southern Asia, who have obtained such excellent results, both as regards the quality of their rubber and financially, may serve as an incentive, and that we shall shortly have upon the market notable quantities of fine *Castilloa* plantation rubber.

[1] Clouth, *Gummi, Gutta-percha, und Balata*, 1899, p. 39. Trans., p. 56.

Within the last two or three years America has put on the market yet another kind of rubber known as Guayule. The North Mexican tableland produces a shrub—*Parthenium argentatum*, A. Gray, also known scientifically as *Synantherea mexicana*—in large quantities. The bark of the shrub contains no latex, but the cell-sap appears to contain the rubber-producing substance in suspension. The rubber is obtained from the plant in the following way:—The plants are dried, milled and pounded, then macerated with hot water, with or without the addition of caustic soda, the cream of rubber which floats to the surface being then sieved in order to remove as much as possible of the fragments of plant tissue. The sieved product is partly freed from water by pressure, made into the form of loaves, and packed in sacks. Guayule cannot, indeed, be completely purified, but forms at the moment, on account of its low price, a much-desired material, although its resin-content is very considerable and its pungent, aromatic smell cannot be destroyed.[1]

Whilst the greater part of American rubber is obtained from large trees, Guayule forming an exception, in Africa the vines of the genus *Landolphia* are at present the principal rubber-producers. Besides the numerous vine species, however, certain trees, in particular the species of *Kickxia* (*Funtumia*), play some part in rubber production; further, the rhizomes (undergound stems) of certain small shrubs, amongst them *Landolphia Henriquesiana*, Heim (formerly called *Clitandra Henriquesiana*, K. Schumann), yield the so-called herb- or root-rubber. Rubber-collection in Africa is still in a very primitive condition. In spite of all regulations and prohibitions, robbery of the trees, resulting in their destruction, is still largely practised. The methods of coagulation are still very varied. The latex is either allowed to stand, with or without previous dilution, until the rubber separates; or, to effect a rapid separation of the rubber, acid plant juices—for example, the juice of wild citrons, or Bossassanga-juice—are added; or the latex is sprinkled as it flows from the incision with an acid plant extract or with salt water, thus enabling the collector to draw away the rubber in the form of a thread or ribbon, which can then be wound up into a ball; or the negro smears the latex over his body, where it is allowed to dry, and is then rolled up into the form of balls or strips. Sometimes typical pieces of rubber are found in one and the same parcel, which clearly show that the individual native

[1] With reference to the future supply of Guayule rubber, see *Board of Trade Journal*, 11th June 1908.

collectors have employed quite distinct methods of collection. The quality of African rubbers varies very much even amongst parcels of the same origin. A cursory examination of the announcements of auctions published by the registered Antwerp brokers, which in every case give a correct idea of the condition of the lots coming under the hammer, is sufficient to show this. Unfortunately there is to be found against so many brands of rubber otherwise known as good, the warning: "*fort collant*" (very tacky); "*fort chargé de matière étrangère, de sable*"; "*en fermentation*," etc. (containing a large amount of foreign matter, or sand; fermented, etc.).

Generally speaking, African rubbers vulcanise a good deal more slowly than Para and Ceara, and require more sulphur—particularly the more resinous sorts—and higher vulcanising temperatures. The smell of the drier sorts of African rubber is, as a rule, quite tolerable, sometimes even pleasant; but the softer sorts generally possess a most unpleasant smell. The drier sorts usually give a much lighter-coloured sheet, after washing and drying in the factory, than do the softer kinds. There are only a few sorts of African rubber which are constantly of a very good quality, and amongst these should be named in particular the so-called "Massai niggers" of French Guinea and Sierra Leone, the "red" and "black" Kassai of the Congo, Equateur, Upper and Lower Congos, Lopori, etc.; and in the case of East African sorts, Mozambique "balls" and "spindles." In the case of Lopori, Equateur, and similar sorts of Congo rubber, considerable variations in quality no doubt occur, but the quality which is designated "Prime" from these sources is always pretty constant; at any rate the slight variations that do occur are of practically no importance in the case of goods vulcanised by heat. The medium and lower sorts of African have a very high resin-content. It may be mentioned that certain sorts of Madagascar rubber have the reputation of being particularly suitable for ebonite manufacture. In the Gold Coast colony, in West Africa, *Hevea brasiliensis* is also cultivated. In several of the African colonies Government regulations have been framed prescribing the planting of a certain number of rubber trees for every given quantity of rubber collected. If these regulations were strictly conformed to, the wholesale destruction in the African rubber districts, which was at one time feared, would be prevented. Such a long period must, however, elapse between the planting of the tree and the first tapping, that competent authorities fear that the total rubber output of Africa will drop during the next few years. Finally, rubber cultivation has been taken up in the Cameroons,

and amongst others the "Kamerun-Kautschuk Compagnie A.-G." has been registered in Berlin with a capital of three million marks.

In Asia rubber is obtained from a number of different trees, the latex from which is worked up together, as in the case of the vines. For this reason it is even more difficult than with African rubbers, leaving out of consideration the finest qualities obtained from the plantations, to determine the origin of commercial sorts of Asiatic rubbers. Amongst wild Asiatic rubber-plants *Ficus elastica* holds a premier position, but *Willoughbeia firma* and *flavescens*, *Urceola esculenta*, *Leuconotis eugenifolius*, *Calotropis gigantea*, and *Cryptostegia grandiflora* also yield rubber. The solid rubber is obtained either by skimming the latex and drying the cream so removed, or by boiling the latex until the rubber separates from it; to a great extent, also, by the addition of a kind of gypsum or other substances which have a chemical action on the latex, or by simply allowing the latex to flow from the tree and dry upon the trunk or on the ground. The value of the rubber obtained varies a great deal. In some brands it is customary to distinguish between no less than four different qualities. The rubbers obtained from indigenous Asiatic plants are usually rich in resins, and, like Africans, behave sluggishly on vulcanisation.

It has already been mentioned that *Hevea* is being successfully cultivated and employed as a rubber producer in Ceylon and the Malay Peninsula. *Ficus elastica* has also succeeded well in the Dutch Sunda islands, and intelligent treatment of the latex has already resulted in the production of a thoroughly well-prepared rubber. This plantation rubber will also become, in the near future, a permanent feature of the market, gradually increasing in quantity, for at the beginning of the year 1906 a "Borneo-Kautschuk-Compagnie A.-G." was formed in Berlin with German capital, in order to cultivate rubber in plantations.

There is no doubt that plantation rubber has a brilliant future before it. By the skimming process, which is almost universally employed on plantations, rubbers are obtained, not only in the case of *Hevea* latices, but also from *Castilloa* and *Ficus*, which leave practically nothing to be desired, and which have the distinguishing characteristic that they contain no dirt, and as a rule no appreciable quantity of proteins and putrefactive bodies, the natural resins of the particular latex being practically the only impurities present. Their permanently pale colour is also one of the decided advantages attending their use.

Latices do not contain solid rubber as such, but a substance

which is capable of being transformed into rubber partly by mechanical and partly by chemical agencies. By extracting a latex with ether, and carefully evaporating the ether from the extract, the rubber-yielding substance is left behind as a thick oil, which is transformed into solid rubber when rubbed with a glass rod or treated with a little acid. The change which takes place during this solidification is at present regarded as a process of polymerisation.

The "rubber-substance" proper is an unsaturated hydrocarbon, or possibly, to speak more correctly, a mixture of unsaturated hydrocarbons. According to the investigations of C. Harries, caoutchouc appears to be a polymer of cyclo-dimethyloctadiene. In addition to this "rubber-substance," rubber contains varying proportions of resins, from which it may be freed without difficulty by extraction with hot acetone in a Soxhlet or similar apparatus, provided that only thin, washed and dried sheeted rubber be used for the extraction. If after this extraction with acetone the residue be further extracted with carbon bisulphide, chloroform, or some other solvent of rubber, the "rubber-substance" dissolves and goes into the extract, and there remains a residue consisting partly of organic, partly of inorganic substances. This residue frequently contains appreciable quantities of nitrogen-containing substance, which is designated, in general terms, mucilage or protein substance. If care has been taken, in coagulating the rubber, to keep it as free as possible from albuminoids—as in the instance of Ceylon Para—traces, at most, of nitrogenous matter are found in the residue, which does not, when incinerated, give off the characteristic smell of burning hair or horn. If, however, coagulation has been carried out in such a way as to retain practically the whole of the albuminoids of the latex in the rubber, the insoluble residue gives a very marked smell of burning hair or horn when incinerated. The inorganic substances mentioned as being present in the insoluble residue, or in the ash, may consist partly of such impurities as were not removed by the washing process, but are also partly derived from organic salts contained in the rubber.[1] Para rubber generally contains (chiefly) calcium salts, while African rubbers contain ferrous salts, and Ceara magnesium salts.

Generally speaking, it is desirable that a rubber should contain only a low percentage of resin, and as little albuminoid and other organic impurity as possible. A small amount of albuminoid matter, provided it is in good condition and free from bad

[1] Henriques, *Der Kautschuk und seine Quellen.* Dresden, 1899, p. 25.

smell, as, for example, in the case of Para, is, of course, quite harmless. Further, the rule may be laid down that the commercial value of a rubber as well as its physical properties—especially after vulcanisation—are roughly proportional to the percentage of rubber hydrocarbons present in it. This, as is well known, is likewise true for different kinds of guttapercha. This statement is, of course, only strictly true for cases where the rubber hydrocarbons do not differ from one another very much in their degree of polymerisation. Valuation on the results of chemical analysis does not, however, do away with the necessity of making certain physical and manufacturing tests. One is unable to decide from the results of a chemical examination whether a particular rubber will be certain to yield on vulcanisation a floating product such as will bear some weighting with pigment, or whether the ebonite prepared from a given rubber will take a good polish or not. Every branch of the rubber industry makes special demands on the rubber to be used in it, and suitable tests must be adapted to these special demands. To this circumstance must be attributed the fact that while one manufacturer swears by a particular brand of rubber, another finds it to be of quite inferior merit, simply because it is quite unsuitable for his particular purposes. In many instances when judging of the usefulness of a rubber, another factor comes in, to which just as much importance has to be attached as to the results of chemical analysis or of practical tests, the question, namely, as to whether the rubber under consideration is always to be had in sufficient quantity. Large factories produce certain goods on such a colossal scale that they cannot risk basing all their calculations upon the use of certain rubbers, if the sorts in question cannot be purchased without difficulty at any time and in sufficiently large quantity. For this reason the smaller factories stand in the advantageous position of being able to cover a considerable portion of their requirements in crude rubber by opportune purchases of small parcels. When these facts are taken into consideration, it is easy to understand why certain sorts—for example, "Massai niggers"—upon which large factories can rely are regularly purchased at prices which do not actually represent their true value, while small lots of the finest Congo sorts can be had comparatively cheap.

In addition to true rubbers, "pseudo"-rubbers are used in the rubber industry to quite a large extent. These "pseudo"-rubbers consist essentially of resins containing a small percentage of a rubber hydrocarbon, and come on to the market as "Paste" or

"Flake." Of late these pastes have been coming not only from Liberia, the Gold Coast, Gaboon, and the neighbouring countries, but also from Central America, under the name of "Mono Rubber." Besk or Pontianac, also called Gutta Jelutong or Dead Borneo, is interesting from the fact that the resins, of which it chiefly consists, behave exactly like the resins of true guttapercha and are probably closely allied to them.

The following table gives some analytical data for a number of different kinds of raw rubber. The very complete raw rubber tables of Drs. Henriques and Soskin, given in Herbst's *Gummi-kalendar*[1] from year to year, may be referred to in this connection. These tables give not only accurate information as to the geographical origin, trade-name, export towns and botanical origin of every single commercial sort, but also include important notes as to their appearance and properties, average price, mean loss on washing, and resin-content.

Name of Rubber.	In the Washed and Dried Rubber.				
	Resins.	Oxygen.	Protein.	Inorganic.	Pure rubber.
	per cent.	per cent.	per cent.	per cent.	per cent.
Para, fine	1·9	2·2	2·9	1·1	91·9
,, entrefine	2·0	2·3	4·1	1·3	90·3
Ceara	2·1	2·4	3·3	4·5	87·7
Columbian	6·8	6·8	3·5	1·0	81·9
West Indian	8·6	7·2	10·4	3·2	70·6
Massai	6·4	6·6	7·4	2·8	76·8
Kassai	5·6	5·4	7·9	2·1	79·0
Upper Congo	6·1	5·6	12·4	3·2	72·7
Madagascar	7·2	5·8	6·8	1·2	79·0
Batanga	12·4	8·9	12·7	2·7	63·3
Thimbles	9·1	7·8	8·4	3·6	71·1
Lopori	5·9	5·7	7·2	1·8	79·4
Mozambique	5·8	5·8	6·1	1·9	80·4
Borneo, I.*a*	8·0	5·9	10·8	2·2	73·1
,, III.*a*	15·0	9·0	14·9	3·8	57·3

The Physical and Chemical Properties of Rubber.—The physical and the chemical properties of rubber are of almost equal importance, so far as the rubber industry is concerned, though one particular chemical property is of outstanding interest, the property, namely, of combining with sulphur or chloride of sulphur to form vulcanised rubber.

Rubber, well-cleansed and dried, has a specific gravity of from 0·925 to 0·967 in the case of samples which have been

[1] Steinkopff & Springer, Dresden.

carefully freed from enclosed air. Rubber is a bad conductor of heat and electricity, and extensive use is made of its electrical insulating power. By friction or pressure rubber becomes electrified, this property being put to a practical use in the case of certain electrical machines in which ebonite discs are used instead of glass.

Good sorts of rubber are transparent in thin sheets, particularly when stretched. Thicker sheets have a yellowish-white to yellowish-brown colour. Rubber may be coloured by admixture with pigments. The mineral pigments are specially suitable for colouring purposes, the lakes of the aniline dyes, on a barium sulphate or alumina base, being almost completely absorbed, even when added in considerable quantity. The use of aniline lakes is possible, however, when it is a question of producing an ultramarine shade, or of colouring the surfaces of goods. The results which are obtained by the admixture of pigments with rubber may, in a sense, be compared with those obtained on mixing the same pigments with oil, when one is dealing with colours which in the dry state lack brilliancy. Further reference will be made later to the changes of colour undergone by pigments under the conditions of hot vulcanisation, a subject of great importance.

At ordinary temperatures — say about 17° C.—unvulcanised rubber has considerable elasticity and pliability. When subjected to low temperatures its elasticity is temporarily destroyed, as is also its pliability, though to a somewhat less degree. When, however, the rubber once more attains the ordinary temperature, these two properties are completely restored. If a strip of unvulcanised rubber be stretched and while in that condition be moistened with water and the latter caused to evaporate rapidly, the rubber remains in its extended condition. When gently heated, unvulcanised rubber softens, and can then to a certain extent be welded together. In a similar manner rubber may be formed into compact masses by powerful compression, especially at surfaces which have been freshly cut. This property also belongs, though in a less degree, to lightly vulcanised rubber. When unvulcanised rubber is gently warmed and kneaded (masticated) it gradually attains a more and more doughy, highly plastic condition, apparently undergoing a process of depolymerisation, in the course of which the molecules, originally very complex, become increasingly simplified. Extensive use is made of this property of plasticity, in a variety of ways, during the manufacture of rubber goods. Rubber

which has been rendered moderately plastic gradually reverts, on cooling and storage, to its former elastic condition. When unvulcanised rubber is heated slightly above the melting-point of sulphur, it becomes soft, and will then dissolve considerable quantities of sulphur, at first without showing any signs of vulcanisation. If, however, the molten sulphur be allowed to interact with the softened rubber for a sufficient length of time, or at a somewhat higher temperature, chemical combination between the sulphur and the rubber gradually takes place. This process is termed "vulcanisation," and consists in the simple "addition" of sulphur to the unsaturated rubber hydrocarbon, no substitution, with its consequent elimination of hydrogen sulphide, taking place. If hydrogen sulphide or analogous compounds be produced during vulcanisation, their formation must be attributed either to the presence of some resinous or other foreign substance, or to the correct time or temperature of vulcanisation being considerably exceeded, resulting in decomposition of the vulcanised rubber, accompanied by a breaking-down of the rubber molecule. The vulcanisation of rubber is dealt with more fully later on.

When rubber is melted it remains soft and sticky on cooling; when ignited, it burns with a smoky flame. In the dry distillation of rubber a number of hydrocarbons are formed, and upon the nature of some of these erroneous conclusions were formerly based as to the chemical constitution of the rubber molecule, which was regarded as a polymer of "isoprene."[1] Professor Tilden has, moreover, stated that he obtained synthetic rubber from isoprene by polymerisation, but attempts which have since been made to repeat his experiments have not resulted in the production of rubber. As already mentioned, rubber may be regarded with a fair degree of certainty—according to Harries' investigations—as a polymeride of cyclo-dimethyloctadiene.

In certain cases rubber is vulcanised by means of chloride of sulphur, instead of molten sulphur, either in solution or in the form of vapour. This so-called "cold" vulcanisation depends upon the chemical addition of sulphur *plus* chlorine to the unsaturated rubber hydrocarbon, also without substitution. An account of this process also will be given in the chapter on vulcanisation. A number of other addition products of the rubber hydrocarbon are known; for example, those with bromine, oxides of nitrogen, and, in particular, ozone. A while ago it looked as though the nitrogen oxide-addition products would prove to be of great service in

[1] See Ditmar, *Der pyrogene Zerfall des Kautschuks*, Dresden, 1904.

rubber analysis, but the expectations formed in this direction have so far remained unfulfilled. [The methods which involve the use of the bromide would appear to be more hopeful.]

Rubber which has been vulcanised to the stage of soft rubber, and which is therefore in reality only partially vulcanised rubber, remains unsaturated to a greater or less extent, and can therefore be vulcanised still further without any difficulty, until the stage of hard rubber (ebonite) is reached. The activity of partially vulcanised rubber due to its remaining double linkages, results also in its ready oxidation by the oxygen of the air, and this is essentially the cause of the perishing of soft rubber. This oxidation is favoured by the action of sunlight and high temperatures, as well as by admixtures which increase the porosity of the rubber. Further, rapid oxidation may be brought about by the action of a solution of hydrogen peroxide in ether or acetone. Contrary to a widely-spread notion, a comparatively high percentage of resins in a rubber does not affect the durability of the goods made from it, provided that it has received correct treatment and has been carefully vulcanised; at any rate, the resin content *per se* does not facilitate oxidation. There is just as little accuracy in the oft-repeated assertion that high resin-content in a rubber brings about porosity in the goods made from it. By using the right proportion of sulphur, and selecting the temperature of vulcanisation with care, products free from pores can be made from rubbers rich in resins.

Rubber is not appreciably affected either by alkalies, or by dilute acids. Strong acids, which act as dehydrating agents, and particularly sulphuric acid, char it. Strong nitric acid stains rubber a deep yellow and dissolves it, on heating gently, with decomposition. When left in contact with water for a long time rubber absorbs notable quantities of it, becoming white in colour. In strong ammonia it swells up. Most solvents for fats, such as carbon disulphide, benzol, the various distillates from petroleum, ether, the chlorides of carbon, turpentine oils, rosin oils, etc., dissolve rubber. Solution is always preceded by a considerable swelling-up of the rubber. Only carbon disulphide, benzol, coal-tar solvent naphtha, and the petroleum benzines have, however, been used technically up to now.

According to experiments made by Henriques there is scarcely an organic liquid, especially amongst those of high boiling-point, which does not act as a solvent of rubber to some extent when heated with it for any length of time. This should always

be remembered in connection with the analysis of vulcanised or unvulcanised rubber.

The Oxidation of Crude Rubber.—Crude rubber has, relatively, little tendency to oxidation. What is usually called "oxidation" in the case of crude rubber is a process which has actually nothing to do with the oxidation of rubber, for what happens is that a portion of the rubber acquires the consistency of bird-lime without any corresponding increase in the amount of resin or in the oxygen-content, as shown by analysis. This so-called oxidation is generally most noticeable in rubbers rich in nitrogen, which still contain latex, or of which the proteins are in a state of putrefactive fermentation. The heat to which it is exposed during transport has a softening action on rubber. Rubber rapidly absorbs oxygen when exposed to its action, either in solution, or when merely distended by a solvent, or when kept stretched.

Crude Rubber Storage.—For this purpose cold, dark cellars are suitable. The parcels of crude rubber are here loosely piled up, separated by wooden partitions arranged like the shelves of an oven, so that sufficient free space is left between the separate balls and heating is thus prevented. Store-rooms which are in a warm situation, or damp rooms in which moisture and water can collect on the floor, should be absolutely avoided. The floor of the store-room should, if possible, be cemented, and be inclined towards a drain.

The Mechanical Purification of Crude Rubber.—*Washing.*—As already stated when dealing with rubber-gathering, most rubbers contain a quantity of impurities mechanically mixed with them, such as sand, wood, stones, fragments of plant tissue, salts, etc., and in addition to these, as a rule, a quantity of water which is quite small in good sorts, but in other kinds, especially the cheaper ones, is much more considerable. Hence arises the need for most careful purification of the crude material in order to free it from these foreign substances before proceeding to work it up further. The greatest care should be taken to obtain as pure a washed rubber as possible, for a badly-washed material may lead to very unpleasant consequences in the course of the later stages of manufacture. For this reason the supervision of the washing department is one of the most important duties in the factory. The purification is carried out in the following manner:—The crude rubber is first put into the vessel shown in fig. 6, and described in the section on the "washing shop," where it is softened by hot water and then rinsed. The crude material as it reaches the

manufacturer is not in a suitable condition to be put straight through the washing rolls, partly because it is too hard, and partly because the separate pieces are too large. It is, however, not advisable to soften the rubber unduly by too prolonged a heating, as this would result in loss of "nerve" in the rubber, and would cause it to become sticky. Similarly it would be a great mistake to leave the rubber, once it has been softened, to lie about and get dry, since it is then very susceptible to oxidation, especially if the latex happened to contain much protein substance when coagulated. Generally speaking,

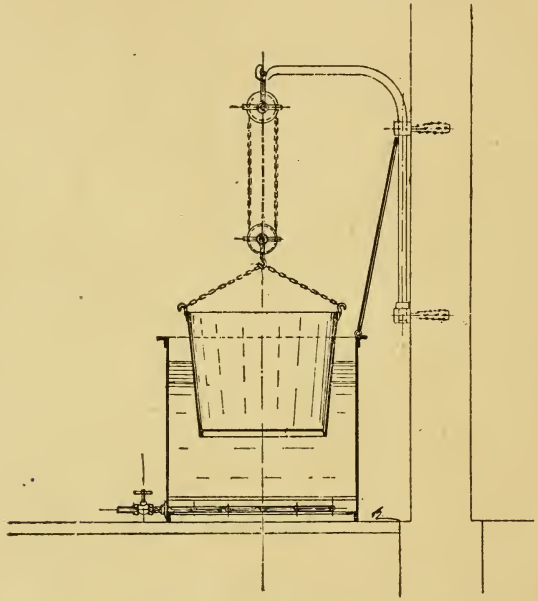


FIG. 6.

heating for from three to five hours is sufficient to soften the rubber; after this the surface is rinsed with water, to remove impurities adhering to the lumps of rubber.

If the lumps are not too large they are now at once taken to the preliminary washing rolls (crushing rolls), whereas the larger pieces are first cut up on a hand-driven cutting machine with circular knives, worked by means of crank-handles, before being put through the crushing rolls (figs. 7 and 8). The cutting machine referred to is of quite a new type, and is to be distinctly preferred to the circular saw. At this stage the actual mechanical "washing" of the raw rubber is begun. The material is brought on to the washing rolls, a detailed description of which will be given in the next section. At present it need only be said that the

crushing rolls break up the rubber into small pieces; during the process a continuous stream of water is allowed to flow between the rolls, with a two-fold object: first, to wash away a large proportion of the dirt contained in the rubber, as well as the soluble impurities; and, secondly, because the cold water prevents the rubber from becoming too hot and consequently deteriorating in quality, for in any case the cleansing process itself does not improve the "nerve" of the raw material. Still, this method

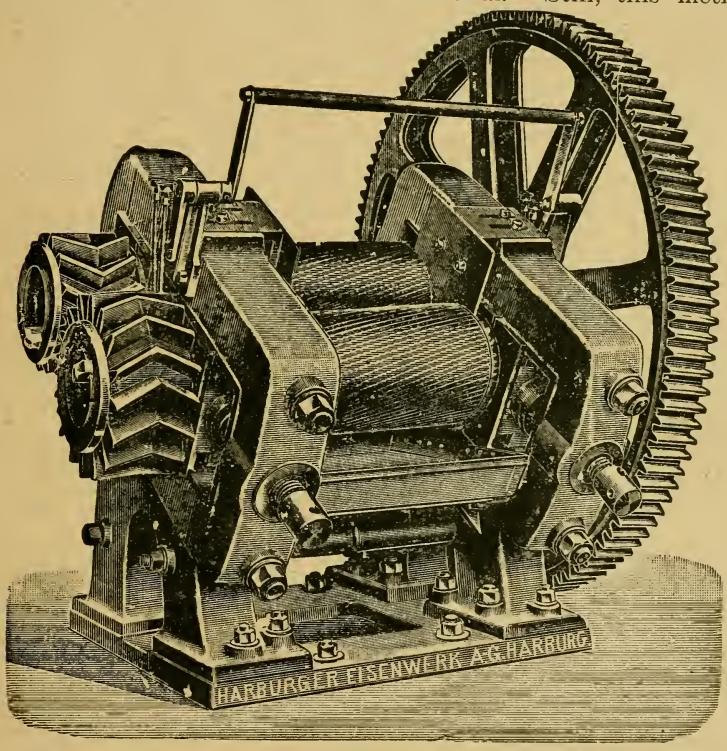


FIG. 7.

of purification is preferable to any other, and especially to the chemical method, quite apart from the enormously high working cost which would be associated with the latter, without any corresponding advantage to the quality of the rubber. When the rubber has been through the crushing rolls, the small pieces are thrown into a tank of water near at hand, and the material is then passed on to the second pair of rolls (see fig. 9), which are set up more closely than the first. Here it is broken up into still smaller fragments, water being still allowed to flow freely over the rubber the whole time. In this second stage of the

process every fragment of the rubber is broken up, and the water, penetrating all interstices, washes out every particle of foreign substance. The usual practice is now to sheet the loose fragments of rubber together on the same rolls, but it is better not to do so (indeed with the rolls shown in fig. 9 the difference in speed of the two rolls would be too great to allow of the formation of a sheet). The small irregular pieces into which the rubber has been broken up should rather be put into the washing

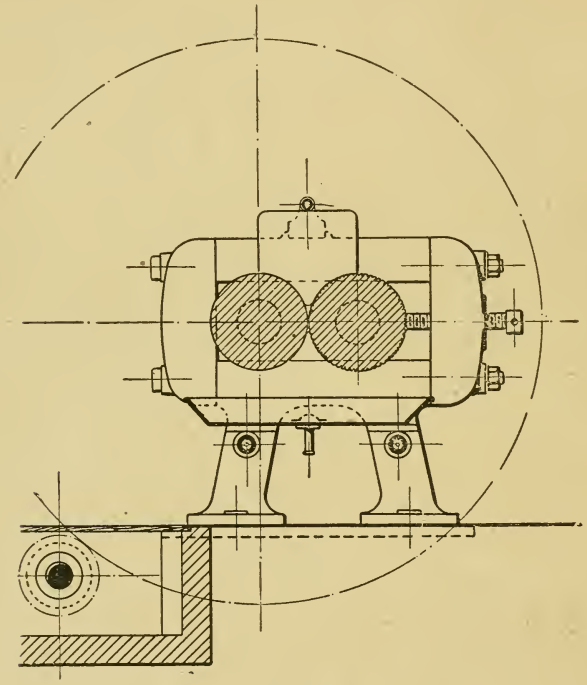


Fig. 8.

hollander (fig. 10). This machine does not, like those formerly used, serve to break up the rubber, but rather to remove the fibrous matter as well as the particles of sand and wood which adhere to it, by swirling it up with water. To this end the two rolls of the hollander are designed, not for crushing, but rather for beating and stirring up the rubber. The hollanders formerly used for actually washing the rubber have not proved to be particularly serviceable. As will be gathered later, from the design of the hollander, all sand, etc., adhering to the rubber is able to settle out from it, without being again taken up. After separating the sand and wood from the rubber and renewing the bath, the mass may be treated with

a weak soda solution, a process which is particularly advantageous in the case of qualities which are impregnated with large quantities of salts in mechanical admixture. The soda-washing must of course be followed by washing in clean water. After being washed in the hollander the raw material is put through a pair of washing rolls (fig. 11), where the fragments are united into the form of a sheet, a gentle stream of water flowing over them the while. The rubber must be run through more than once, if necessary, until all the separate fragments have united to form a wide band, resembling in appearance a pelt, and having a uniform crêpe-like surface. The ease or difficulty of this sheeting process varies with the kind of raw rubber being washed. The various sorts of Para are the easiest to wash, while Mid- and Central-American sorts, which are very dry, as also Guayaquil, often cause difficulties. In these cases the water used must be slightly warmed before a sheet can be obtained. The same difficulty occurs with "scrappy" sorts—*e.g.* "Arracaty scraps," which cannot be caused to unite at all, and have to be dried as they are, a mass of little pieces. Specially low grades, such as Liberian flakes and Angolas, can only be washed with very great difficulty, and it is advisable to go to work with the greatest possible care in these cases.

The mechanical washing process being designed to free the raw material from all mechanical impurities, and from impurities soluble in water, it must be carried through conscientiously, so that no foreign matter is left in or on the washed rubber, and nothing but water remains to be removed by drying. Before speaking of the drying process, however, the plant and arrangement of a washing shop must first be dealt with in technical detail, and a few words said about the machines.

(a) *The Washing Shop.*—The washing plant is now to be briefly considered. As may be gathered from fig. 1, this plant is shut off from the other mills, so that the steam, water, and dirt which accompany the washing process may not come in contact with them. It should also be mentioned here that the shafting which drives all washing and milling rolls runs in a trough beneath the rolls. The rolls are mounted on rails over a trough 70 cm. deep, (as in fig. 8, except that the trough containing the shaft would be better placed vertically beneath the rolls). Coming to the separate pieces of apparatus set up in this department, fig. 6 represents the heating apparatus, made of sheet iron, and heated by means of a steam coil at the bottom of the tank; in this tank is suspended a second smaller iron bucket, the sides and bottom of which are

made of perforated galvanised iron, and which can be raised and lowered by means of a crane. Two such pieces of apparatus are sufficient for a daily production of 500 kilos. of washed rubber. The bucket is filled with the rubber to be washed, the water let in until it covers the rubber, and then the lid is closed down and steam turned on.

Then, after the steam-valve has been closed, and the hot water, which often has a very unpleasant smell, has been run off, the bucket is hoisted half-way out, the spray fixed above it is turned on, the bucket swilled through with water at a suitable pressure, and then let down into the heater and steeped in cold water.

The preliminary washing rolls (figs. 7 and 8) now generally in use consist of a strong under-frame on which rest the bearings for the support of the cast-iron rolls. The bearings of the back roll are supported by the back frame-cap, whilst those of the front roll are movable, and rest against the ends of the setting-up screws. The fixed roll is driven from the shafting by means of the large spur-wheel, whilst the movable roll is driven from the axle of the back roll by toothed-wheel gearing. The rolls revolve inwards at unequal speeds. The back roll is grooved, or channelled, to assist in crushing up the rubber passing between it and the front roll. It is advisable to insert a safety-block between the loose bearing and the setting-up screw, to safeguard the teeth and frames against fracture by undue pressure; the block, which will be the first to go, can be replaced at a small cost. The approximate size of a pair of modern washing rolls is about 75 cm. long on the roll, with a diameter of 45 cm. The speed of the back roll is about twelve revolutions per minute, whereas the working roll makes only about six revolutions per minute. The bearings are protected by scrapers set into the sides of the rolls and pressed against them by steel springs fixed at the back. The scrapers are capable of being adjusted to make up for wear.

A collecting tank of galvanised iron is placed under the rolls to collect the water and the disintegrated rubber. About 4 cm. below the edge of the tank is a perforated sheet-iron tray, and about 10 cm. below that a coarse movable sieve. At the bottom of the tank, which is at a depth of about 45 cm. and slopes slightly downwards from front to back, is the outlet pipe, and vertically above it an overflow pipe. Both pipes lead into the first catch-pit, which is common to all the washing rolls, and in which any pieces of rubber which get washed away are recovered. The second pair of washing rolls (fig. 9) is of similar construction and size, but the rolls them-

selves are smooth, and work with still greater friction; the back roll makes about twelve revolutions per minute, whilst the greatest number made by the front roll is four. The collecting tank of this machine has two sieves movable towards one another, of which the upper one is inclined towards the front, the tank itself sloping towards the back, and the excess of water is in this case led off, not from the bottom, but from a point at a short distance below the upper edge of the tank. The lower outlet is only used for the purpose of cleaning out the tank. On this account the tank is so constructed that the particles of dirt and wood, after passing

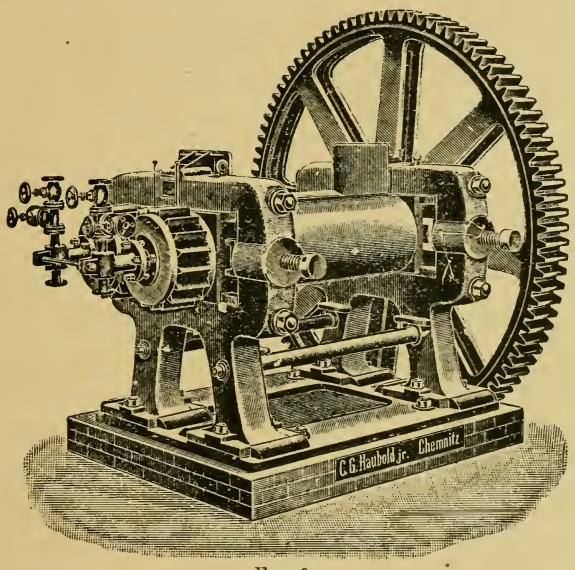


Fig. 9.

through the rolls with the water, are washed away at once towards the outlet at the back, whilst the rubber drops towards the front. By this means the impurities washed out are prevented from falling on to the pieces of rubber again. Over the middle of each pair of rolls and about 60 cm. above them is a spray-pipe with a number of small holes; from this flows the clean washing water under a high pressure. Condensed steam, which is used in some factories, is not to be recommended, on account of the dirt and oil which is nearly always present in it. Fig. 10 shows the present-day type of hollander. It is best walled round with cement to a depth of $\frac{3}{4}$ metre below and a height of $\frac{1}{2}$ metre above the ground level, and every part should be carefully plastered. The roll is to be regarded rather as an agitating and rubbing apparatus

than as a disintegrating roll. Beneath the blades of the roll the bottom of the hollander slopes upwards, falling away steeply on the other side and terminating in a sand-trap in connection with

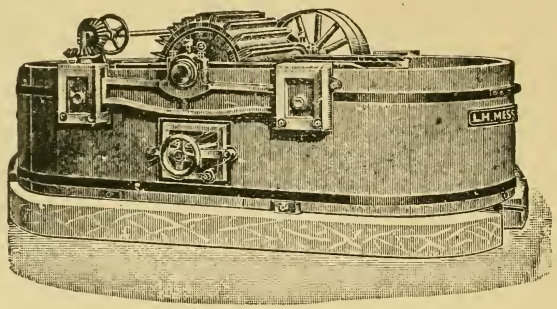


FIG. 10.

the outflow trough. In this manner the sand is directly removed and so cannot come into further contact with the rubber.

Finally, the washing rolls, illustrated in fig. 11, in which one roll is placed vertically over the other, are brought into use.

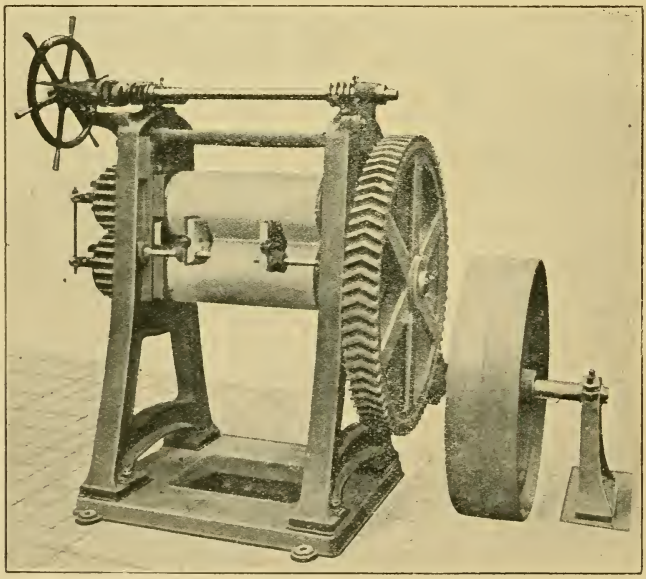


FIG. 11.

Whereas the rolls of the machines previously described have a diameter of 45 cm., in this case 25 cm. is ample, the length of the roll being 80 cm. The speed of the lower roll is twelve revolutions per minute, that of the upper ten revolutions. A spray-pipe is

arranged about half-way up the top roll, the spray being directed downwards on to the lower roll. In front of the latter, and level with the top of it, is a small movable tinned-iron table on which the loose pieces of rubber are heaped and from which they are pushed into the mouth of the rolls by means of a scraper. On the opposite side of the roll, the sheeted rubber, directed to some extent by guides fixed at the back of the rolls, falls on to a conveyor, by which it is carried under the lower roll back to the man in front; a cover protects it from the water running off the lower roll. In this way any small particles of dirt are completely

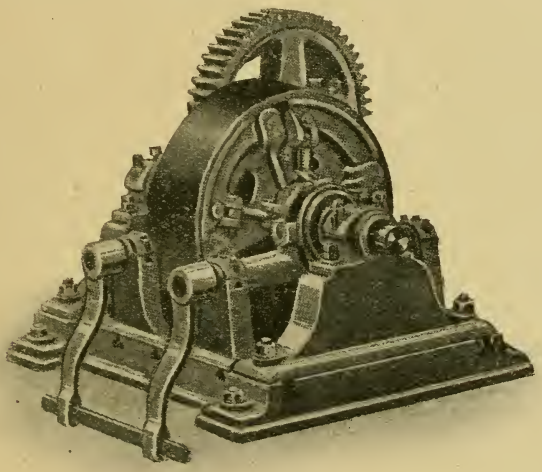


Fig. 12.

removed, being carried away by the water from the lower roll without coming into contact with the rubber again.

It may be mentioned that an automatic coupling is inserted between the series of washing rolls and mixing mills; the hand-pull or the wire rope above each mill can be easily reached and the whole series of mills be stopped at once by means of the automatic coupling with which the wire is connected. There are other equally reliable devices for rapidly throwing the rolls out of action; for example, an instantaneous release by Fr. Gebauer of Berlin, illustrated in fig. 12. This is an exceedingly practical device, and the release can be operated in any position, even with the foot, on all sides of the rolls. This release acts by means of a friction-clutch, which can be at once thrown in, without any difficulty, by a sharp pull of the chain.

Heywood and Bridge's friction-clutch (fig. 12A) consists of an inner casting, comprising a boss B, which is keyed on to the shaft A, and from which are two arms C and a rim D. The rim is divided transversely, but retains its unity through its connection with the arms, and through them with the boss. In the rim, at the transverse divisions, sockets G G_1 are cast, and in these are placed nuts H, in which work the ends of right- and left-handed screws F. These screws are actuated by means of levers L L_1, attached to a sliding sleeve M, on the shaft. When the sleeve is moved nearer to the face of the clutch, the rim D is caused to expand, and binds upon the internal surface of an external shell N, rigidly attached

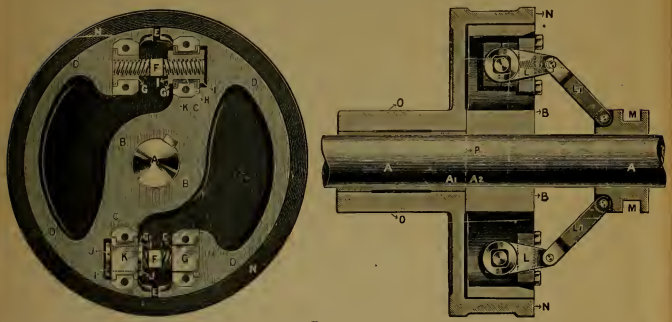


FIG. 12A.

to the other shaft-end. On moving the sliding-sleeve away from the clutch-face, the rim contracts, and the machinery is thrown out of gear. Coupling and uncoupling can be effected without any jarring by means of this contrivance.

In this department there are also centrifugal machines (fig. 13) for whirling the rubber as free from water as possible before transferring it to the drying-room and vacuum-drying chambers. The advantages and disadvantages of the vacuum-drying apparatus are fully dealt with in the next section.

(b) *Loss on Washing and Drying.*—The loss, or wastage, undergone by raw rubber in the course of purification and drying is sometimes very considerable, reaching in many cases as much as 65 or 68 per cent. It is very unequal in the different sorts, and frequently,

also, different parcels of the same sort vary considerably, differences of 14 to 18 per cent. being not uncommon.

TABLE SHOWING THE LOSS ON WASHING OF A NUMBER OF RAW RUBBERS.[1]

Trade Name.	Maximum Loss.	Normal Loss.	Minimum Loss.
	per cent. about	per cent. about	per cent. about
Bolivian and Peruvian Para	16	14	14
Upriver, fine Para, hard cure	17	15	13
Islands, fine Para, soft cure	20	18	15
Entrefine, medium Para	25	22	18
Manaos negroheads	28	26	23
Scrappy negroheads	40	30	26
Cameta negroheads and scrap	35	28	23
Caucho or Peruvian ball	25	21	18
Caucho or Peruvian slab	40	35	32
Mattogrosso Para, genuine	25	22	20
Mattogrosso sheet	40	35	30
Ceara or Manicoba scrap, I.*a*	25	20	18
,, ,, ,, II.*a*	35	30	24
Columbian strip	12	10	8
Equador, Esmeralda, Guayaquil sausages, and strip.	32	28	24
Centrals, West Indian, Columbian, Guatemala, Nicaragua strips, scrap, sheet and slab.	42	32	24
Rio, Santos, Mangabeira, Bahia, Pernambuco, Maranham sheet.	50	40	30
Guayule	35	28	20
Gambia, Senegal, Bissao ball, I.*a*	45	35	25
,, ,, ,, II.*a*	50	40	35
Cape Coast, Benin, Accra lump, I.*a*	45	38	32
,, ,, ,, II.*a*	50	45	40
Sierra Leone, Massai, Conakry niggers or twist.	24	22	20
Kassai, red and black, Lopori, Equateur I *a* sorts.	10	7	4
Aruwimi, Mongalla, Sankuru, Lake Leopold	15	12	10
Thimbles	55	45	38
Batanga marbles and clusters	45	38	30
Mozambique, Donde, Mohorro spindles	20	16	10
,, II.*a* marbles and balls	30	25	22
Madagascar pinky	35	30	28
,, black	38	32	30
,, niggers	65	60	50
Borneo I.*a*	50	43	38
,, II.*a*	53	45	43
,, III.*a*	65	60	55
Dead Borneo, Pontianac, Jelutong, Besk	77	70	60
Assam, Rangoon I *a*	18	15	12
,, ,, II.*a*	40	35	30
Java I.*a*	18	15	12
,, II.*a*, Penang II.*a*	40	35	32
Ceylon Plantation Para	4	2	0
Red Tonquin	12	10	8

[1] *Cf.* also the raw rubber tables given in Herbst's *Gummikalender*, 1908, pp. 96-113.

Drying Washed Rubber.—The method of drying the sheets of washed rubber must depend entirely upon the properties of the different kinds of rubber, and upon the uses to which they are to be put. To state in general terms that such and such a method is the best would hardly be fair, for each of the ordinary methods of drying has its own special advantages and disadvantages. The method of drying to be employed in any given case must therefore be decided upon for that individual case.

Generally speaking, far too little attention is devoted to drying washed rubber in a rational way. The drying is still frequently carried out in a very unworkmanlike manner, clearly showing how

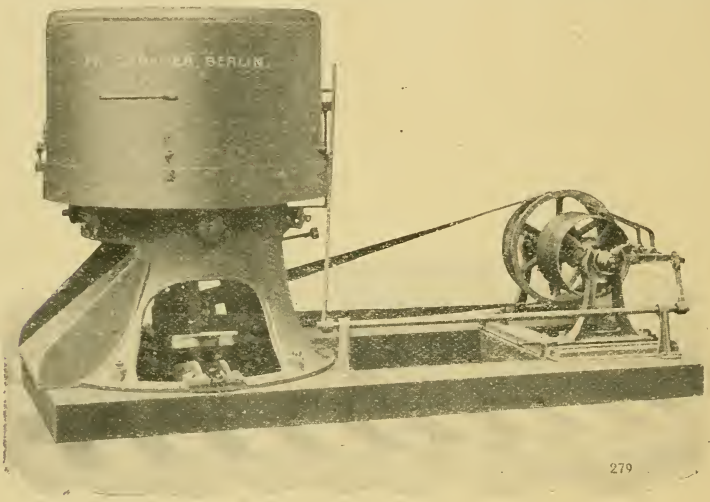


Fig. 13.

little intelligence is brought to bear upon this important subject. Raw rubber dried in such an unsuitable way exhibits absolutely no good properties; the places in which it is dried are generally of quite insufficient dimensions, so that it looks as if one were drying rags instead of dealing with an expensive material like rubber, sensitive to the most diverse influences. Very often no special drying-rooms are provided at all, in order to economise space; and it is not an infrequent occurrence to find the boiler-house serving as a drying-room. The value of raw rubber dried in such places is very doubtful, the dust which settles on it being the least of the evils to which it is exposed. The vacuum chambers introduced some years ago have not proved to be of practical advantage in all cases.

The best apparatus for drying rubber is the drying-room, designed and constructed throughout in the way best adapted to

the properties of the washed rubber which is to be dried in it. This is not so simple a matter as it would appear to be. It will be well, therefore, to consider somewhat more fully the characteristics of the washed raw rubber which is to be dried. The greater part of the water which has to be removed is merely superficial, and its removal presents no difficulty. On the other hand, the water actually occluded within the rubber can only be removed with great difficulty, if one does not wish to fall into the error of vacuum-drying. The mechanically held, superficial moisture can be readily removed from the rubber sheet in a few days by means of a gentle heat; it is not advisable, however, at this stage to raise the temperature above 50° to 60° C., since resinous rubber will not stand that amount of heating. The temperature should therefore not be raised to such a degree as would be most favourable to superficial drying, and the complete drying of the sheet of rubber should be carried out at as low a temperature as possible. It is a well-known fact that as soon as the superficial moisture is evaporated the surface of the sheet contracts so that the water still present gets completely enclosed, and can only be driven off, through the rubber which surrounds it, with great difficulty, or not at all. The diffusion-pressure depends very little on the temperature or on the atmospheric pressure, but, on the other hand, the condition of the warm air in the drying-room, especially its hygrometric state, is a matter of essential importance. High temperatures are therefore not necessary for complete drying, provided that proper care is taken to see that the air is kept dry, and in this way the detrimental effect of high temperatures upon the rubber may be avoided.

The conditions of the drying-room must, therefore, be such as to (1) render possible safe and rapid drying of the washed rubber, and (2) prevent further oxidation of the rubber. It must be remarked that goods made from rubber which has not been thoroughly dried are subject to rapid deterioration, and that imperfectly dried rubber may also, under certain circumstances, lead to the production of porous goods. Then it should also be remembered that highly oxidised rubber is always of less value, and, as is well known, the oxidation of the washed rubber by atmospheric oxygen proceeds very rapidly. The large surface-area of the washed sheet is very favourable to this oxidation. These facts should be taken into account in designing the drying chambers. Spacious drying-rooms are disadvantageous and unsuitable, since they cannot be filled or emptied in one operation. To fill them gradually with wet

sheets of rubber often has disadvantages, for it tends to check the drying of those batches which are already in the drying-chamber and which are partly dried, and to prolong the time necessary to dry them completely. A preliminary whirling of the moist sheets in a centrifugal machine, after they leave the final washing rolls, and before they are put into the drying chamber, may be strongly recommended. The drying-rooms should be small chambers which can be filled at one operation, and the drying should be carried out in such a way that the moist air surrounding the rubber is being continuously displaced by a fresh supply as dry as possible. A good circulation of the air inside the chambers must therefore be

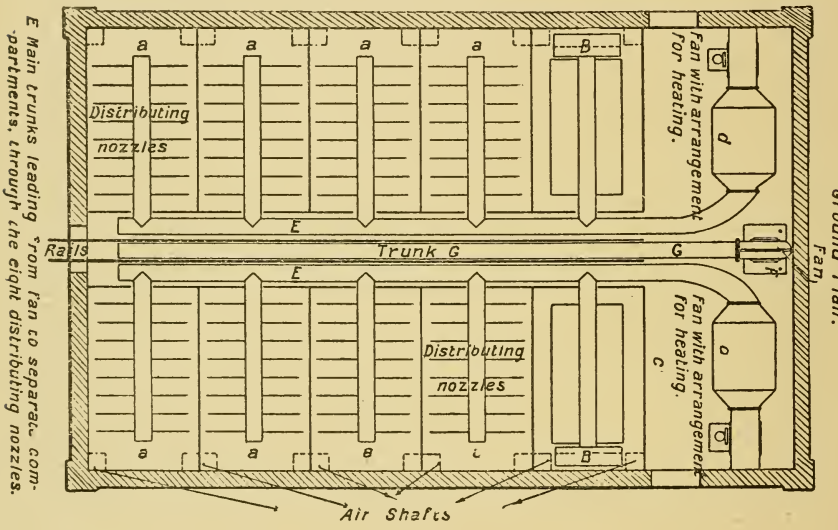


FIG. 14.

maintained, and the air must be as dry as possible and heated to a suitable temperature.

A modern arrangement for drying washed raw rubber is shown in figs. 14 to 17. The size of the complete plant, as well as of the individual drying chambers, depends upon the approximate weight of rubber washed per day. In the diagram fig. 14 the plant is assumed to cover an area of 3×5 metres, and to reach a height of 4 metres, of which about 3 metres is useful space. Sufficient free space is provided for the warm ascending air to collect, and from there it is drawn away upwards. The chambers *a* are warmed and aired from the main air trunk E by means of eight equidistant adjustable air-nozzles, which force the warm air upwards. The chambers are fitted with 20 to 25 drying-poles which can be hoisted

up by means of wire rope; over these the sheets of rubber are loosely hung, the current of warm air streaming past them. The chambers B are fitted with racks, and the current of warm air

Section through portion of drying chamber fitted with racks.

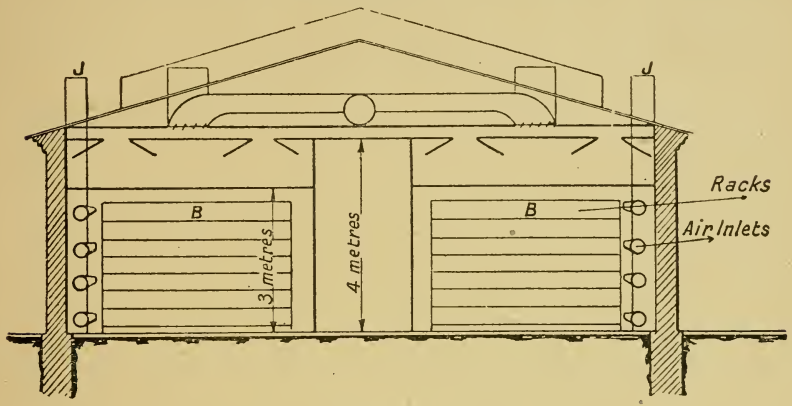


Fig. 15.

enters at the side (fig. 15). The space C contains the heating and ventilating plant; in it are situated two large Sturtevant blowers, with heating attachments D, which supply the necessary warm air.

Section through portion of drying chamber fitted with poles.

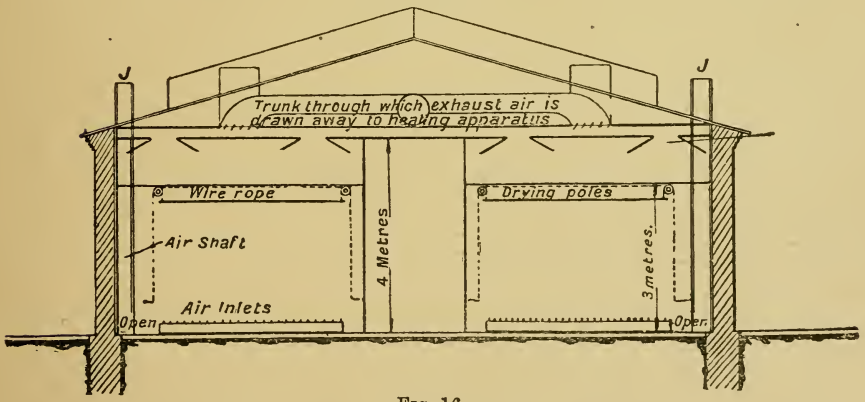


Fig. 16.

The fan F, with trunk G, serves for the supply of cold air and can be connected to the separate chambers as required for cooling purposes. The air-supply to the drying chambers is regulated from the outside. The removal of the spent air is regulated by the trunk H passing through the double top of the chamber; the air is

returned at once to the heating apparatus. On the other hand, the steam is exhausted through the channels I, and led away into the open air. All the drying chambers are without windows; the passage-way down the middle between them, which is provided with rails, is lighted by means of a top-light.

A new mode of drying which looks very promising may still be mentioned. The drying is effected by means of special centrifugal machines, the washed rubber being first broken up into small pieces and not run into the form of a sheet. The particles of water are frozen by means of a special arrangement, on the under frame and outer jacket, and driven from the rubber by gently warming.

A great number of rubbers cannot be obtained in sheets suitable

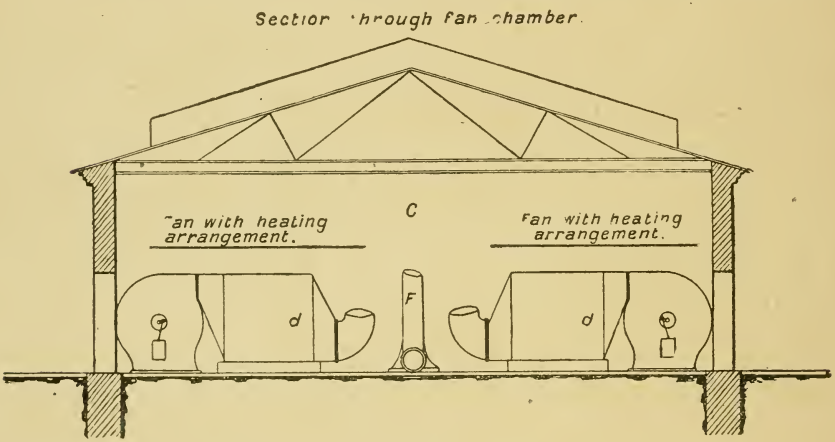


FIG. 17.

for carrying about. The softer sorts, in particular, are so greatly affected by the gentle heat of the drying chamber that even short sheets break away from the drying-poles and fall to the ground. Moreover, considerable quantities of rubber are required for a very large number of rubber goods which present less difficulty in their manufacture, or for such goods as must be pretty highly vulcanised, and for these, as for soft kinds of rubber, drying in a vacuum-chamber (fig. 18) is to be recommended. The sheets are put into the chamber on perforated iron shelves, the door is closed, the temperature raised from 50° to 60° C. or even higher under special circumstances, and the chamber exhausted by means of an air-pump. In the more perfect forms of apparatus, amongst which that of Passburg in particular is in most general use, drying is completed within an hour, provided one starts with sheets which have been centrifugalised. It is strongly recommended to "batch

up" vacuum-dried rubber immediately on its removal from the chamber, in order to prevent oxidation of the hot dry material.

Air-drying may, under certain conditions, bring about slight oxidation of the rubber in some cases, but never results in *depolymerisation*, in consequence of the heating. Vacuum-drying, on the other hand, although not facilitating oxidation, results in quite an appreciable depolymerisation as a result of the high temperature

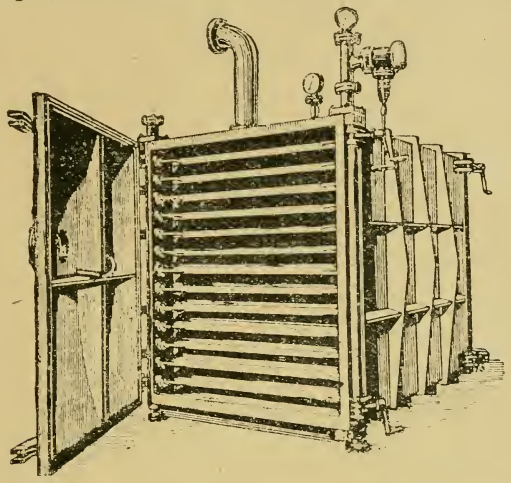


Fig. 18.

to which the rubber is raised, and this effect is the more marked in the softer sorts of rubber.[1]

The Further Working-up of the Dried Rubber.—The practice of running the washed rubber into thin sheets greatly facilitates drying by considerably increasing the surface area. When, however, the rubber has to be stored for any length of time, or when it is to be used for the manufacture of cut-sheet, it is advisable—in the latter case absolutely necessary—to reduce the rubber to some more solid or compact form, in the first place in order to reduce oxidation to a minimum by making the superficial area as small as possible, and secondly, in order to produce homogeneous blocks, free from pores, from which to prepare "cut-sheet." It was formerly the general practice to work or knead all dried rubber into solid masses, but it is nowadays the object of the manufacturer to avoid these processes whenever it is at all possible, experience having shown that it is wise to avoid all unnecessary treatment of rubber on the rolls, not only on the score of expense, but on account of the

[1] *Cf.* on this important subject of the drying of washed raw rubber, articles in the *Gummi-Zeitung*, 1906, xx. pp. 656, 681, 738, 789, 843, 1107.

heating and depolymerisation which is brought about by such treatment. In modern manufacture, on the large scale and by rapid methods, there is generally no need for prolonged storage of rubber after washing, and it may therefore be at once worked up into the various mixings.

To effect this the mixing mill described below is set in motion, steam being passed through the hollow rolls. It is advisable to warm up the rolls to such an extent that mixing may proceed rapidly, and prolonged working, which is so detrimental to the rubber, be avoided. The rolls should not be allowed to get too hot, or the rubber may also suffer from that cause; the temperature must therefore sometimes be brought down by means of the cold water supply through the rolls. During the process of mastication between the rolls the rubber becomes spontaneously heated.

At a first glance, rubber-mixing appears to be a very simple process, the mill itself automatically bringing about a complete admixture even if. left unattended. Yet mixing is a process that needs careful watching and intelligent manipulation on the part of the workmen engaged in it, otherwise the rubber can be very easily overworked ("killed"), the ultimate result of which would probably be goods of poor quality and little durability.

As a rule there is one man to each mixing mill; only very occasionally does it happen that one man has to look after two mills at the same time; in that case the mills should be placed opposite one another, so that there is no need for the man to leave his place, but only to turn round. The mixer generally receives the mixed ingredients in galvanised iron boxes or tubs. His tools consist of a scoop, a hand-broom, a spanner for opening out or closing up the rolls, a short knife for cutting the rubber off the roll, and a sieve fitted with a hinged lid, with which he sifts the powdered "compounds" on to the rubber. The actual mixing is carried out in the following way:—The mixer takes from the vessel containing his material, first of all the raw rubber, passing the separate sheets between the rolls and working them up into a fairly smooth sheet surrounding the front roll, which is kept rather hotter than the back one. When this stage is reached and the rubber is sufficiently soft, the other ingredients are gradually added. The mixer now passes his knife obliquely across the rubber sheet on the front roll, lifts up a portion of the sheet and turns it over across the roll, repeating this process a number of times. As the rubber is meanwhile getting hotter, the rolls must be more and more thoroughly cooled. Finally the mixer cuts off strips of the

rubber, rolling them up and laying them aside until the rolls have attained a temperature suited to the last stage of mixing, whereupon the little rolls of rubber are again put through the mill and mixed together to form an apparently homogeneous mass, which is cut from the rolls without delay.

The above method of mixing is, however, by no means one which can be applied generally. Mixings which contain much paraffin, pitch, oil, or the like, must be treated differently from the so-called dry mixings containing much waste and fibrous material. Great damage may be done by unintelligent mixing. The manager should, therefore, train only intelligent men, with keen powers of observation, for the mixing mills, and should always keep a watchful eye upon the mixing department. Moreover, he should very carefully consider what mixing should be carried out on a small pair of rolls, and for what mixings only the large rolls should be used, for more depends upon this than many people imagine. The fact that certain theorists are opposed to the use of large mills because they are not economical, should not prevent anyone from using large mills in order to treat his mixings with care and produce first-class results. One can only utter a strong word of warning against judging machines solely from the engineer's point of view, or from the point of view of most rapid working and lowest possible working cost; the behaviour of the material under the different conditions should be well considered in addition.

The way in which the different raw rubbers behave on the mixing rolls is different in each individual case. The following rules may be taken, in a general way, as a guide:—

Rubber from species of *Hevea, Sapium, Micranda,* and *Castilloa,* and from *Manihot Glaziovii,* requires rather more heat during mixing than rubber from *Hancornia, Ficus, Funtumia,* and most African *Landolphia* species. "Mozambique spindles" and "red Kassai" occupy an intermediate position. It will be seen that the softer and more resinous African and Asiatic kinds must not be treated in exactly the same way as American sorts, which are freer from resin, and possess more "nerve." This is to be explained partly by the solvent and depolymerising action on the rubber of the rubber resins, and partly by the fact that the degree of polymerisation is actually lower in some raw rubbers than in others.

It is very often desirable to thoroughly work the reclaimed rubber in a pair of rolls running at a high speed before adding it to the raw rubber on the mixing rolls. Substitute should be ground up very fine on well-cooled rolls. Sulphur and mineral additions

must be sifted as fine as possible before adding them to the rubber; they are often mixed together in the dry state in special mixers, and are then dusted on to the rubber with the aid of a sieve, fitted with a cover, or by means of a revolving sieve fixed over the mixing rolls, in order to produce a mixing as devoid of granular structure as possible. Such arrangements for the production of mixings absolutely free from granules are to be found to-day in a state of great perfection in nearly all rubber-shoe and pneumatic tyre factories, as well as in rubber-thread factories. The additional cost of such appliances is not great; the improvement in quality brought about by their use is frequently very noteworthy. The greatest care must be taken during the progress of mixing to prevent sulphur, resin, asphaltum, etc., from melting on one of the rolls and getting baked into thick layers.

In the case of mixings which contain oil, vaseline, paraffin wax, and similar substances, it is often advisable to incorporate these materials either by first preparing the waste with them, or by mixing them with the minerals to form a kind of thick dough and then mixing these with the rubber. This method is not only more cleanly, but also less detrimental to the rubber.

The Mixing and Weighing Room.—This room is used for weighing out the separate constituents of the mixings to be subsequently worked up in the mills. A particularly trustworthy man should be placed in charge of this department. On the one hand, the mixings with which this man is entrusted for the manufacture of the different rubber goods are valuable, being the result of great experience and often of costly experiments, and, on the other hand, it is necessary, in order to avoid subsequent troubles in the course of manufacture or even later, that the various constituents of the mixing be weighed out with the greatest possible care. Even slight errors in weighing may have most unpleasant results, particularly in the case of the sulphur for vulcanisation, the magnesia usta, etc., or, in "floating" red goods, the amount of golden sulphide added. The larger quantities of material should be weighed on a large, comparatively rough pair of scales, which when skilfully manipulated will give perfectly satisfactory weighings. Sulphur and other important materials are, on the other hand, weighed out on a small pair of more sensitive scales, the weights being, of course, accurate, and kept scrupulously clean. Platform balances, although they are to be obtained small, are generally rough, and are not to be recommended for the finer weighings. Moreover, they cannot be adjusted by means of screws as can beam scales. In the case of mixings

which the manager wishes to keep secret, a good plan is to tie up the weights for the different items of the mixing in small bags, and to hand these over to the weighing foreman each time a batch has to be mixed. As soon as the ingredients are weighed out they are carried straight away to the mixing rolls and mixed together. Another method of keeping the mixings secret consists in using counterpoises of various shapes which can be readily distinguished from one another. This, however, is not the place to dilate upon the outgrowths of the traffic in works-secrets, which is still carried on here and there, for it is frequently quite possible nowadays to fathom the secrets of the mixing in a perfectly legitimate way, by

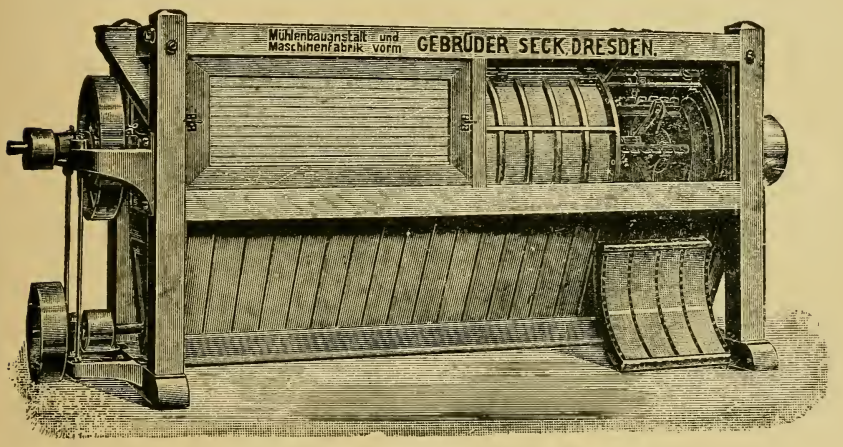


FIG. 19.

carefully devised experiments based on chemical and physical knowledge, in spite of all attempts at preserving secrets.

The ingredients to be mixed with the rubber must be as dry and as finely powdered as possible. The drying is often done simply by heating on stoves. For whiting and other fillers which are used in large quantities special drying plant, consisting of large heaters or long troughs provided with arrangements for stirring, are often used. In dealing with large quantities of material, indeed, the workmen's wages form such an important item that the drying and subsequent sifting are made as far as possible automatic. The object of sifting is to remove all the coarser particles of the substance, as well as pieces of wood which may have got into the material on opening the casks or cases. Sifting apparatus which works continuously, like the cylindrical sieve shown in fig. 19, may be used with advantage; charges of 50 to 100 kilos. (1 to 2 cwt.) at a time can be put through the hopper of this apparatus. The

sifted material is stored in tightly-closed bins. For this purpose it is usual to employ both large wooden zinc-lined bins and galvanised iron ones, as well as small sheet-zinc boxes. It is convenient to keep oils in so-called patent oil-holders, from which they can be pumped out when required. The washed and dried raw rubber is kept in pigeon-holes lined with sheet zinc, and these are best provided with some means of closing them, in order to protect the rubber from dust. Well-galvanised tubs or bins are generally used to hold the weighed materials for the mixing; the bottoms are protected by strong iron rims on which the receptacles can be slid about. Wooden bins lined with sheet zinc are also used sometimes, and in certain cases these are divided into several compartments, so as to keep the constituents of the mixing separate from one another. More will be said as to the composition of the various mixings in a special chapter.

The Mixing Mills.—The machinery for mixing is similar in construction to the washing plant, but on a larger scale. An ordinary mixing mill, such as would satisfy present-day requirements, has rolls 110 cm. long and 450 mm. in diameter, and the approximate weight of such a machine is 3500 kilograms. The cast-iron rolls are hollow, and each is fitted with an independent steam and water supply for heating and cooling respectively. The front, or so-called working roll, runs at 18 revolutions per minute, whilst the back roll makes 26. Fig. 20 shows the form of mill in most general use at the present time; this, on account of its firm build and large size, gets through the work very rapidly, and only slightly affects the properties of the rubber. The setting-up screws should be of fairly large size, and may be provided with pointers moving on discs fixed to the ends of the bearings, and graduated in 5 mm. divisions. This apparatus makes it easier for the mixer to set his rolls regularly at the same distance apart, and when properly used ensures that the two sets of bearings are an equal distance apart.

The sheet-iron boxes beneath the rolls should not be fixtures, but should be provided with wheels so that they can be easily moved backwards or forwards along two rails. The guides at the sides should be of iron; wooden or copper guides are not to be recommended. It is advisable to provide for the removal from the rolls of mixings which readily stick to them, by means of a "doctor," and for this purpose a steel bevelled rail screwed on to a strong wooden base about 6 cm. thick may be recommended. This is suspended, with the bolts fixed to the wooden side, in the bearing-cases. The knife is depressed by means of a lever against the

middle of the roll, and cuts or scrapes off the mass of rubber from it.

The mixing mill should, like the washing rolls, be provided with instantaneous safety-clutches, as already described (figs. 12 and 12A), the most suitable being those based on the friction-clutch principle.

A little further consideration may now be given to the mixing mills fitted with revolving sieves, which have been already men-

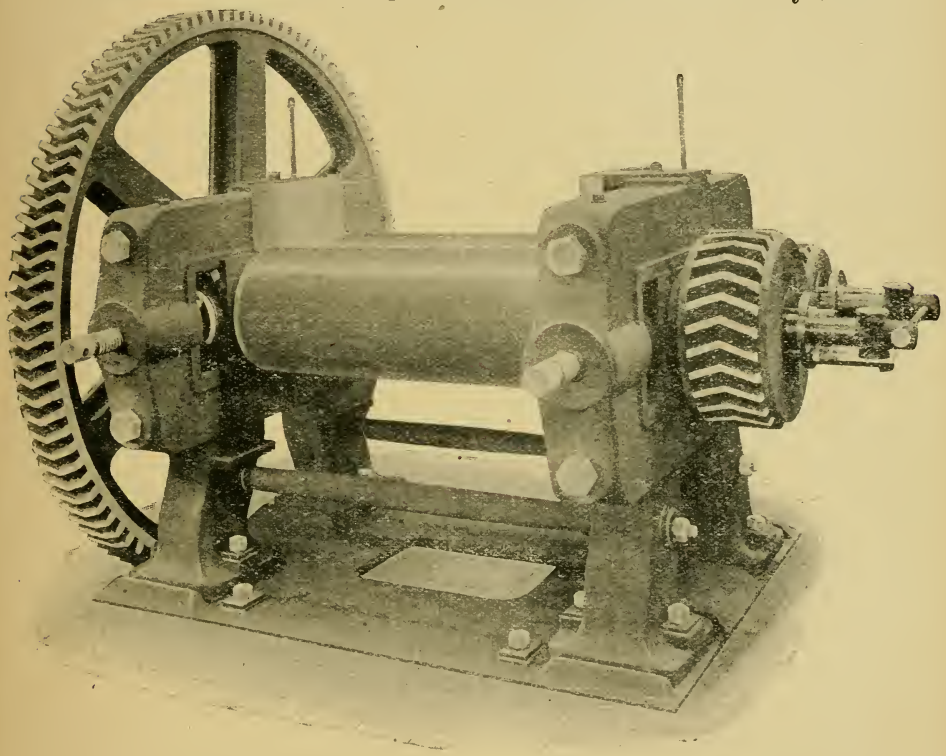


FIG. 20.

tioned. (The rights of manufacturing these machines have been acquired by C. G. Haubold, jun., a firm of engineers in Chemnitz.) The rolls are constructed as in an ordinary mixing mill, but above the front roll at a height of about 20 to 25 cm. (8 to 10 inches) there is fixed a cylindrical sieve containing a revolving brush, driven by toothed-wheel gearing from the axle of the roll (fig. 21). The cylinder can be raised in its bearings in a backward direction by means of an eccentric movement, in order to throw it out of gear. The sifted material falls into a funnel-shaped sieve fixed below the cylinder, and kept in continuous vibration by means of an

eccentric so that the materials passing through the cylindrical sieve are passed through the second sieve on to the rubber. A celluloid cover is fitted over the whole sifting apparatus in such a way that it can be adjusted to the height of the front mixing roll; the edge of the cover presses lightly on the front roll so that it readily adjusts itself to inequalities in the thickness of the material surrounding the roll. The back part of the cover is carried about half-way across the top of the back roll, and is also adjustable. So that the cover may be transparent, only pale-coloured celluloid should be used. This cover prevents the

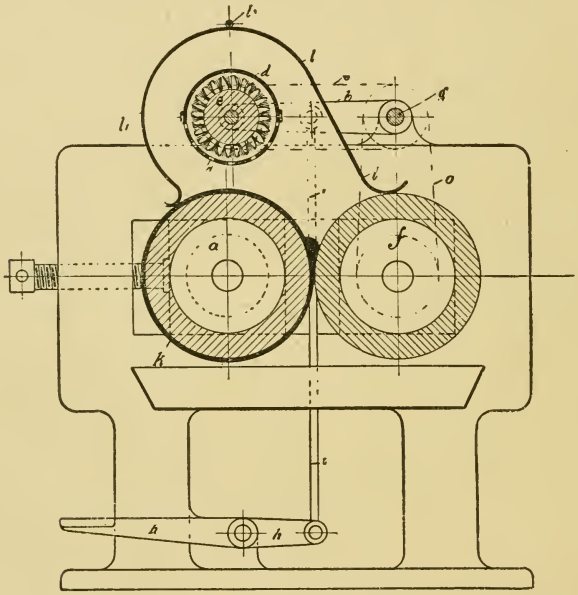


FIG. 21.

inhalation of the fine magnesia dust produced when the sieve is working; any dust which tends to settle on the smooth surface of the celluloid is at once shaken off on to the rolls by the vibratory motion.

The Calenders.—We have seen in the last few paragraphs how the mixings are prepared on the mixing rolls, and we have now to follow the mixed rubber through its further manipulation until it arrives at the stage of hard- or soft-rubber goods.

Before anything more can be done with it, the mass of mixed rubber has now to be run into the form of sheets, the thickness of which, together with the greater or less degree of smoothness of their surface, depends upon the details of the manufacture of the article

for which the rubber is to be used. The strange notion which was very widely prevalent outside the industry for a long time, and which is still in existence here and there, that indiarubber articles such as tubes, balls, syringes, etc., are made by simply casting liquid rubber in suitable moulds, in the manner in which metallic castings are made, is, of course, quite an erroneous one. With only a few exceptions, all rubber goods are prepared from *plastic* material, partly by hand, partly by special machinery. But even so it is the calendered sheet which has to be used for the purpose. The calenders must therefore be looked upon as the centre of the manufacture and of the machinery, and must accordingly be dealt with fully.

As already stated, the calenders are used to run the sheets of rubber, which are then worked up into the most diverse articles, according to the kind of rubber. In whatever manner the sheets are afterwards to be used, uniform thickness throughout the sheet is the first essential to the achievement of good results. Considerable experience is necessary in order to be able to produce such uniformity in thickness, and there would appear to be very few men who really understand the proper working of the calenders. It most cases it is found that a three-roll calender has only two of its rolls in use while the third is running empty; so in "frictioning" insertions it is no uncommon thing to find only two of the rolls in use. Taken as a class, the calender-hand knows very little, or at any rate insufficient, about the principles which underlie that method of working which involves the use of all the rolls. The winding apparatus, which is a most important feature, is in most cases left unused, or even thrown aside as worthless, because the value attaching to the apparatus is not known, and in most instances the fitter charged with the erection of the machine is not clear himself as to the use of it. In order to be able to understand things more clearly, the reader may first of all be made acquainted with the constructive details of the calenders.

In all calenders, whether with two, three, or four rolls, the following points must be specially observed, if the rolls are to work perfectly, and accuracy in running the sheet of rubber is to be secured: the rolls should be of sufficient strength not to spring, and must in every instance be ground true. It is most convenient to have cast-iron rolls 1250 mm. long and 500 mm. in diameter, which have been ground on a Poole's grinding-machine. Three- and four-roll calenders may be driven by a special motor to ensure a uniform speed to the calenders, and to avoid the irregularities

brought about by driving the mixing rolls from the same main shafting. Fig. 21A shows a modern set of three-roll calenders, electrically driven, and provided with a friction-clutch.

In laying down new plant all the gear-wheels should have double-helical, or at any rate helical teeth, the preference being always given to the former, however, for when they are used the motion of the calender rolls is absolutely uniform, as is most markedly noticeable in calendering very thin sheet. Ordinary

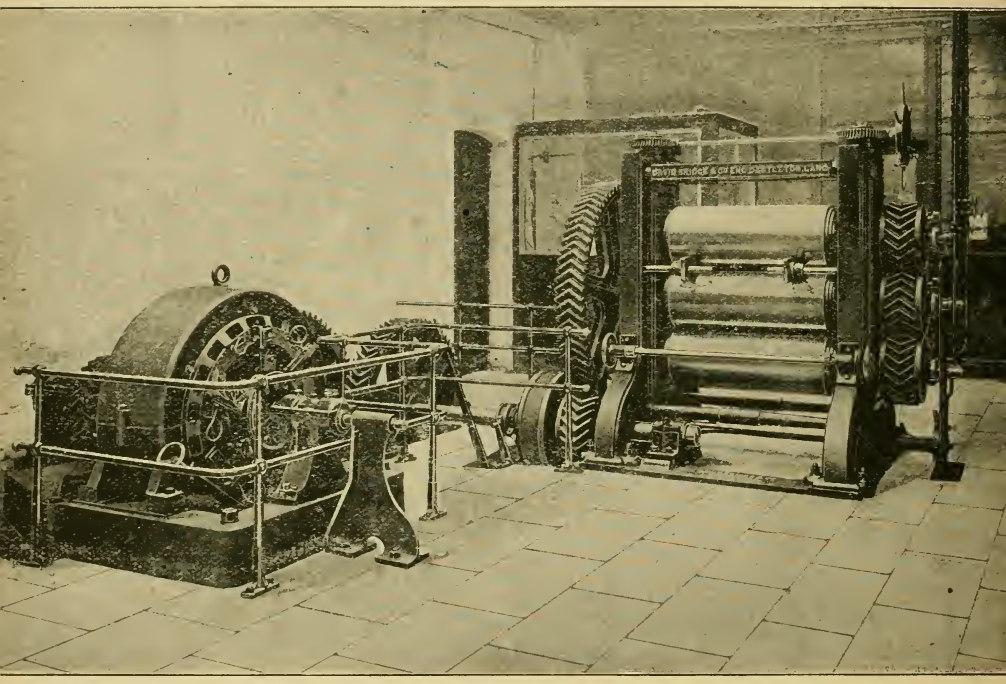


Fig 21A.

teeth always give rise to a certain amount of back-lash, which makes itself evident in the form of striped markings right across the calendered sheet, where the rubber runs thin.

The arrangement for adjusting the top and bottom rolls should be fixed in a convenient position about half-way up the machine, and it should be possible to adjust either top or bottom roll by manipulating a single wheel. The bearings of the middle roll are fixed. The gearing, as also the worm-wheels for the spindles, and the spindles themselves, cannot be chosen large enough to allow of a certain and easy raising and lowering of the rolls. Chain-drive should be altogether avoided, and the vertical shaft with bevel-

wheel gearing should be selected as the best arrangement. The normal speed of the rolls is 4 revs. per minute, but for frictioning the lower rolls should be geared up so as to work with a

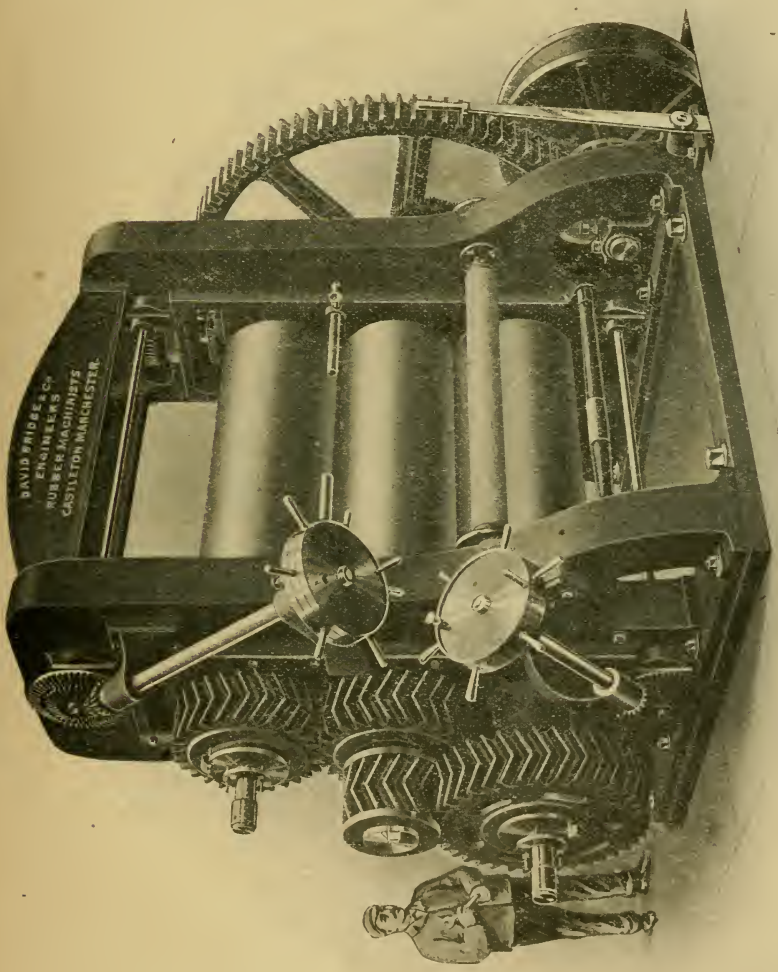


FIG 22.

maximum speed-ratio of 1 : 3. In large factories it is, however, always better to use, for proofing purposes, special calenders constructed for the purpose, as illustrated in fig. 22, and to use the ordinary calenders only for running sheet. It is of fundamental

importance that every set of calenders should be provided with reliable apparatus for heating and cooling the rolls, and that the controlling valves should be placed in a convenient position. Finally, attention must be paid to apparatus for reeling and unreeling, which should always accompany a set of calenders. The method still frequently employed for effecting these two purposes, consisting in the use of a simple wooden roller, on to which the rubber sheet is still more simply wound by several workmen, is quite irrational. On a closer consideration of the process of running a sheet of rubber, it will be found that in the case of the three-roll calenders the upper and middle rolls do the work, and that the distance from the point where the sheet leaves the rolls to the trestle, where it is taken up by the running cloth, is about $1\frac{1}{2}$ to $1\frac{3}{4}$ metres. The faults of such a sheet, and the damage that may be caused to the finished goods by them, are instructive. In particular, the sheet draws up more or less, according to its quality, very considerably and very unevenly; whilst hanging free between the calenders and the winding trestle the sheet gets stretched, and the uneven tension of the winding which follows suffices to produce great variations of thickness in the sheet, quite apart from the creases and folds that are formed. If, however, every workman understood the art of winding calendered sheet on the calenders, and if the apparatus were always in position, these faults would be remedied. Moreover, the use of the apparatus necessitates the attention of only one man in addition to the foreman, whereas in the older method at least two others besides these are necessary to look after the winding, or to hold the cloth and the sheet of rubber apart. The entire arrangement of the apparatus on the calenders is extremely simple, but the bearings must be accurately centred, and the friction-brake must work properly.

On the opposite side from where the rubber is fed in, the unwinding apparatus is fixed to the calender frames, on a level with the axis of the lower roll. The square iron axle, 35 mm. thick, which carries the wooden roller 120 mm. in diameter, rests in two bearings; that on the right-hand side is closed on the upper side by a hinged piece, with a fly-nut, so that it can easily be opened, while that on the left-hand side is a closed bearing in which runs the box which carries the axle. The box is provided with a fixed friction-brake on the other side of the bearing, and by adjusting this the roller is allowed to run free or is kept in check to a greater or less extent. On the other side of the machine—that is to say, on the feeding side, and at the same height as the apparatus

just described—is that for winding up the emergent sheet. One bearing of this can also be opened, whilst the other takes the box with the friction-drive. The roller is best driven from the middle roll by means of toothed-wheel gearing to the friction coupling. If a chain-drive is employed great care should be exercised in getting a chain which is of an even make. Belt driving is quite unsatisfactory, for as the roll of rubber sheet increases in diameter the belt slips, destroying the even tension on the sheet.

When the wooden roller and axle have been put in position in the bearings, the running cloth from the feeding roller is drawn through between the middle and lower calender rolls, stretched tightly over the receiving roller and wound round it a few times. Care must be taken that the cloth lies smoothly on the roller, and rolls up evenly. The calendering of the sheet may now be started.

The mixed rubber is warmed up to a uniform temperature on the warming-up rolls situated close to the calenders; these rolls are quite similar in their construction to mixing rolls, but their use is restricted to warming-up. Care must be taken that the rubber does not become too doughy, and that it is not put into the calenders in large masses, but that strips about 20 mm. ($\frac{3}{4}$ inch) thick and 200 mm. (8 inches) wide, cut from the warming-up rolls, are fed in. In this way one ensures keeping the rubber at a uniform temperature, and the pressure against the bearings of the upper roll remains more constant than if the calenders were fed with large masses of rubber; for while the large mass is still warm, it exerts little upward pressure, but as it cools its pressure increases, causing the roll to lift; on the other hand, as the rubber gets used up the upward pressure again becomes less and the roll drops, the net result being considerable unevenness in the thickness of the rubber sheet. Assuming now that the rolls have been set to the right distance apart, the rubber passes between the upper and middle rolls, round the middle roll, to which it adheres closely until it has gone half-way round, when it is taken up by the running-cloth, which, as has been mentioned, passes between the second and third rolls. Immediately the rubber comes in contact with the cloth the winding apparatus is started: that is to say, the friction rim is drawn into the shell, and the roller begins to turn. The speed of the roller is accurately regulated, so that when the brake is on fairly hard it takes up exactly as much sheet as the calenders pay out. As the diameter of the roll, with its alternate layers of cloth and rubber, increases, the brake is slackened and the friction pulley allowed to slip round, so that the speed of rotation of the

roll decreases as its circumference increases. After a little practice the calender-man can adjust the brake to a nicety, so that the sheet is rolled up without being stretched or creased. In this way the thinnest Para sheet (0·2 mm. thick) can be calendered, and a uniform thickness will be maintained, since the sheets are not stretched, and cannot draw up unevenly. To entirely do away with drawing up, the sheet should be left in the running cloth until it is quite cold, and only then unrolled and made up.

It should be mentioned that the bottom roll should be so adjusted

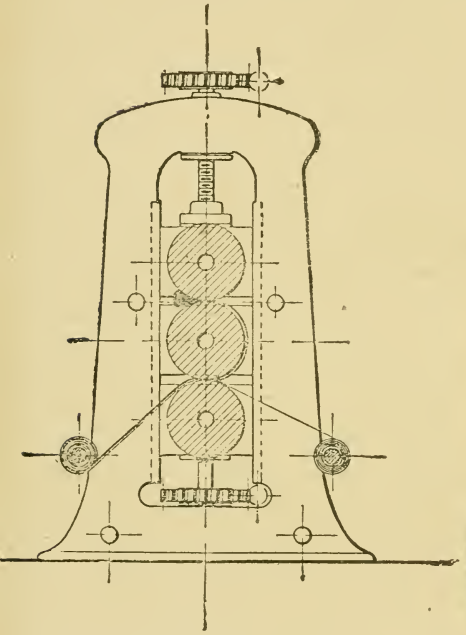


Fig. 23.

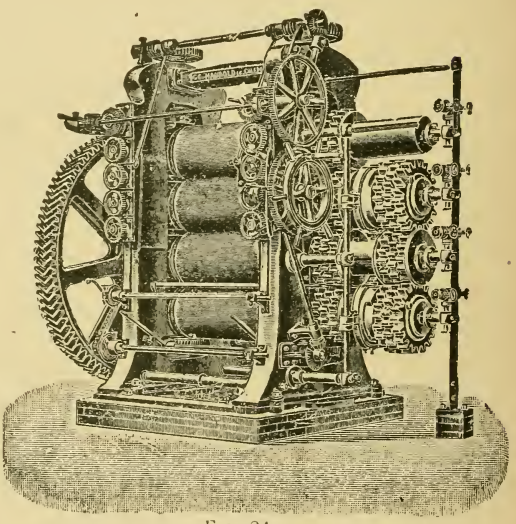


Fig. 24.

as to gently press the rubber against the face of the running cloth. Fig. 23 illustrates the principle of a modern set of three-roll calenders. Such three-roll calenders are chiefly used for running rubber sheet of the better qualities, which must be as free from air-bubbles as possible. But they also come in for doubling the sheets on the calenders, since it is only with great difficulty that, for example, a sheet in a pure rubber quality, $\frac{3}{4}$ mm. thick, can be obtained in long lengths quite free from air-blisters. In that case the calendering takes the following course: in order, for example, to produce a sheet 1 mm. thick, a sheet $\frac{1}{2}$ mm. thick is first run as described, and wound on to the wooden roller. This is then mounted on the axle of the feeding roller (unwinding apparatus),

and the running-cloth, with the sheet of rubber upon it, is passed between the two lower rolls and taken up by the winding-up apparatus; the bottom roll is now closed up towards the second, until the second ½ mm. sheet, now to be run, is pressed tightly on the first, so as not, however, to form blisters or streaks. The whole is then wound up again, as already described, and yields

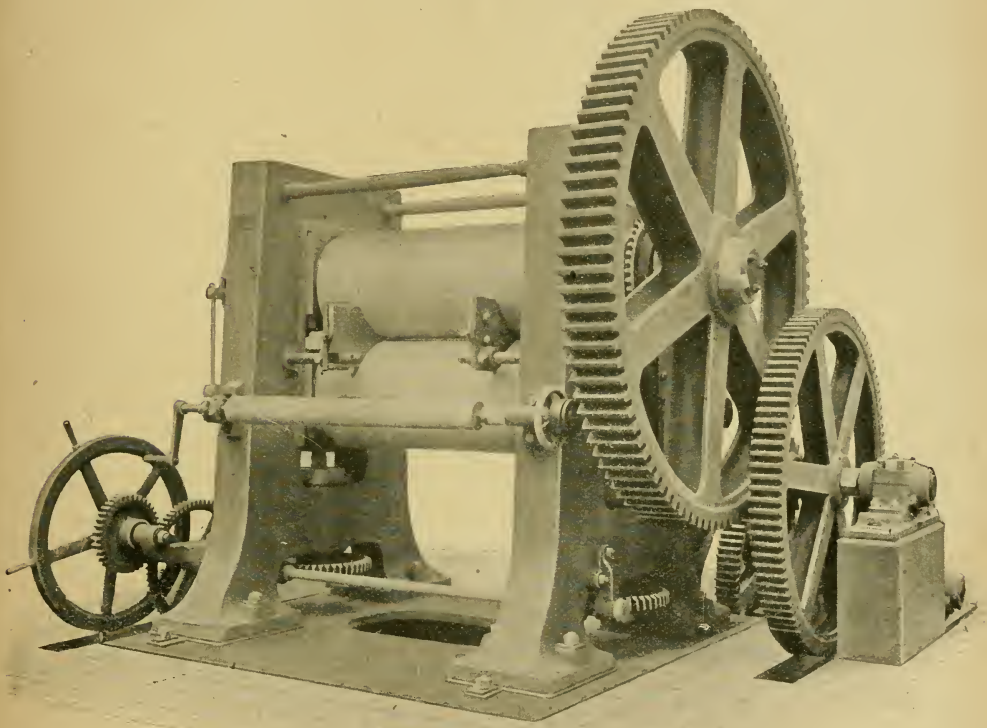


Fig. 25.

a sheet, built up of two layers which cannot be separated from one another again. In this way the various thicknesses of sheet can be built up of different numbers of layers according to the use to which the sheet is to be put. For still thinner sheet, down to 0·15 mm., the four-roll calenders shown in fig. 24 have to be used. The method of using them is similar to that described for the three-roll calenders, only that one actually works with three rolls and uses the fourth to cool the sheet as it is run out.

The two-roll calenders depicted in fig. 25 are chiefly used for

running sheet which is to be cut up for solution, or where uniform thickness is not of importance. If, however, it be required to produce on the two-roll calenders, sheet as even in thickness as possible, for mechanical work, an automatic winding apparatus must be provided, as shown in fig. 22, for the three-roll calenders.

The two-roll calenders (fig. 26) are also often used to run thicker sheet free from blisters, to be used for surgical work, and which must therefore have a smooth surface. The method of doing

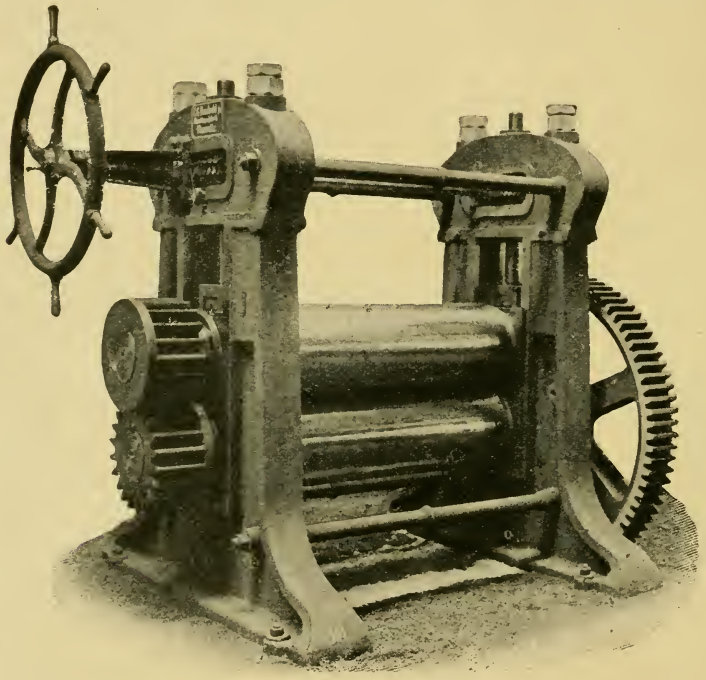


Fig. 26.

this is not to run the sheet out in long lengths, but to allow it to run right round the roll; a sheet equal in length to the circumference of the roll is thus obtained, that is, about 120 cm. long. It is advisable to rub a little vaseline over the roll round which the sheet runs; this helps to give the rubber a smoother surface and allows the air which collects between the rubber and the roll to get away at the sides.

It is also necessary to have a second set of two-roll calenders, of similar construction to that shown in figs. 27 and 27A. This set is chiefly used for running sheet, for ebonite manufacture and also for moulded goods, which is required in thicknesses of from 3 to

10 mm., and which must be doubled absolutely free from air-bubbles. These calenders are used in particular in the manufacture

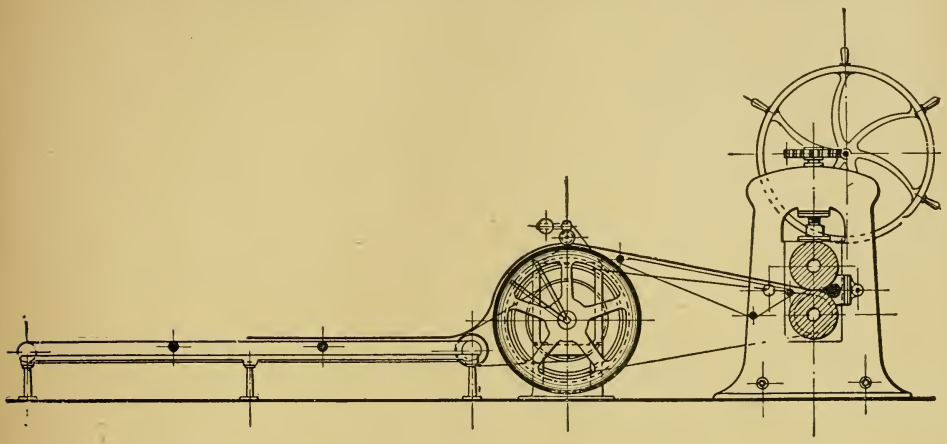


Fig. 27.

of accumulator cases. The separate lengths are only $4\frac{1}{2}$ metres long, but this is quite enough for the purpose. As indicated in the illustration, the machine consists of a two-roll calender with a

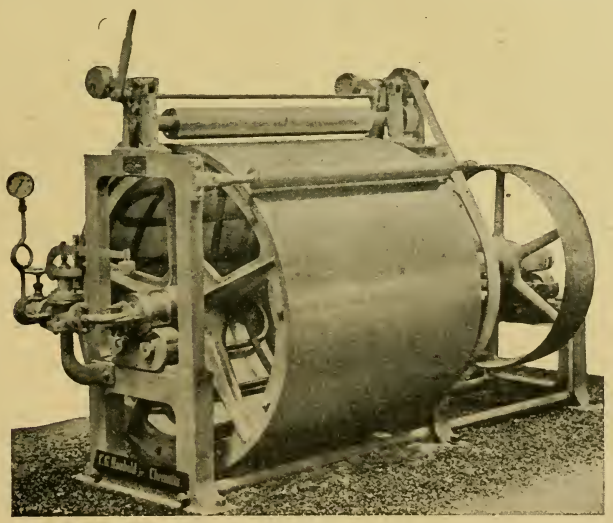


Fig. 27a.

doubler in front of it. The calender rolls are 450 mm. in diameter and 1200 mm. long. The doubling drum is 1300 mm. in diameter, and the conveying-cloth 5 metres long. The pressure-roll is rubber-covered, and its distance above the drum can be adjusted by means

of movable bearings. Pressure is applied by means of weighted levers. The drum is driven from the calenders, and the travelling table derives its motive power from the same source. The rubber mixing, which is run out between the rolls into the form of sheet, passes over the cloth conveyor on to the drum, round which it is wound until the correct thickness is reached, when it is cut off and passed on to the table, by which it is carried away.

It may be mentioned that the rubber sheets can be cut into

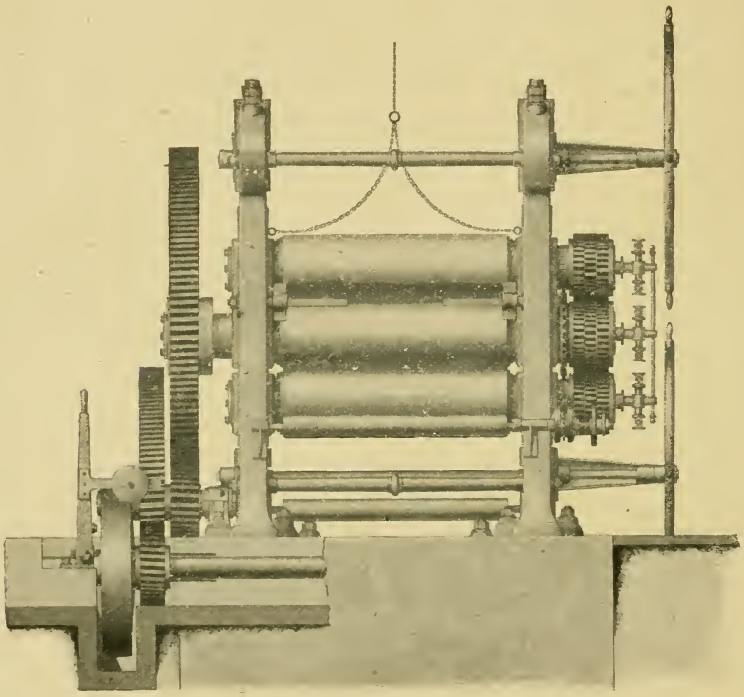


Fig. 28.

strips on the calenders themselves, before being rolled up in the running-cloth. To effect this a cutting apparatus is fixed between the two vertical frames of the machine, about 18 cm. below the level of the middle of the second roll. The knives, fitted in boxes provided with grooves, are fixed upon the spindle between the wheels, can be set to any desired width of strip, are kept in position by means of set-screws and are pressed against the sheet by means of a spring, the strength of which can be regulated; this arrangement results in the sheet being cut through clean.

The spreading calenders shown in figs. 28 and 29 are now generally used for impregnating insertions and fabrics with rubber,

since by the use of these a considerable saving of benzine as well as of time is effected as compared with the spreading machine. As already mentioned, where the plant is a large one it is better to use a machine exclusively for "frictioning." The use of three rolls is nowadays substituted for the American method, in which two rolls only were employed, and which may easily lead to the cloth getting torn. The uppermost and lowest rolls are driven slowly at equal speeds, while the middle roll makes the ordinary four revolu-

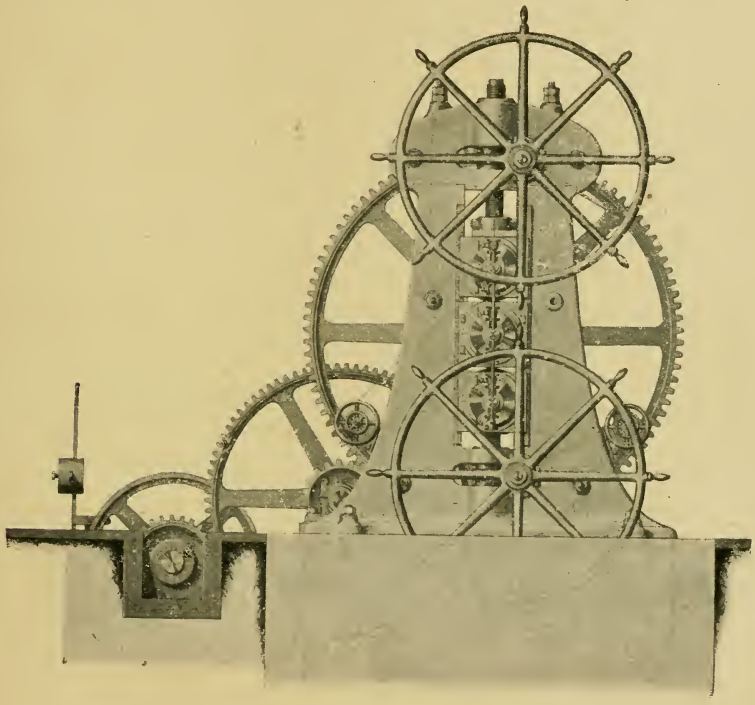


Fig. 29.

tions per minute. The material on which the rubber is to be spread passes, like the running-cloth mentioned above, between the second and third rolls, when it is wound up. The process consists essentially in feeding the rubber into the calenders between the top and second rolls, allowing it to run round the much hotter middle roll in a very thin sheet, the thickness of which is determined by the substance of the cloth to be coated, and by means of this pressing it into the cloth. The third roll, revolving slowly, rubs the thin sheet of rubber deep into the meshes of the fabric, and completely covers it over, filling up and penetrating all the interstices with an even mass of rubber. In carrying out this process,

care must be taken to have the rubber mixing worked up and warmed uniformly, so that it may lie evenly round the roll, and not in too soft or sticky a condition, so that the friction roll can remove it without difficulty. Sticking to the middle roll must in all cases be avoided; it indicates that the particular mixing is not suitable for calendering. With few exceptions the fault lies in having the middle roll too hot. One of the chief aims should always be to keep feeding in fresh quantities of rubber regularly, and not too much should be fed in at a time. It is also essential to success to have the cloth rolled up evenly and tightly on the wooden roller before passing it through the calenders, so that no creases are formed as the cloth is unrolled, and to see that the fabric does not run crooked, which would lead to its getting torn. In rolling up the cloth, as also in dealing with the ordinary running-cloths, it is best to make use of a machine which should always be provided with a calendering plant. This machine has a large heating drum over which the cloth or fabric is carried in order to dry it thoroughly, moisture being capable of great mischief under these circumstances. Behind the drum is a mechanical brush enclosed in a box, by means of which the fabric is freed from loose fibres and dust. Into this the fabric passes as it comes from the heating drum, emerging on the other side, and after passing over the stretcher is tightly wound on the interchangeable rollers. In this way one is always sure of getting clean, dry fabrics.

Having now shown how the mixed rubber is worked up into the form of sheet, we propose to deal in the two following chapters with the important subjects of Vulcanisation and Mixings, and shall then proceed to consider in detail the various stages in the manufacture of a number of different articles.

CHAPTER II.

THE VULCANISATION OF RUBBER.

THE discovery of the process of vulcanisation by Charles Goodyear, an American, in 1839, was not, as one often reads, an accidental occurrence, but came about as the result of investigations which had been carried on by him for years. Goodyear, like many other men of an inventive turn of mind, kept on dabbling with rubber in spite of his numerous failures, and studied the effect of mixing all sorts of substances with it. Through this he was, undoubtedly of set purpose, led to his discovery, and as a result of the experience he had gained in the course of his investigations he recognised, on observing the effect of heat upon a mixture of rubber and sulphur, that the heating was essential to the process. It is a remarkable thing how this hard-pressed man, overwhelmed with debts, succeeded in working out his invention. That he did work it out is clearly demonstrated by the fact that in the description first published by him of his method for the "metallisation" of rubber he gave sufficient instructions for the technical preparation of perfect rubber goods, and that these instructions have even up to the present time lost no essential part of their technical importance; in every instance they are still in the main far superior to any of the processes devised by Goodyear's imitators. Thomas Hancock can only be regarded, in relation to the vulcanisation of soft rubber, as having confirmed Goodyear's results, though Hancock was actually ahead of Goodyear in his application for a patent for his alternative method. Without doubt he must be looked upon merely as the inventor of another way of carrying out Goodyear's invention (in a strictly chemical sense), but, on the other hand, he has undoubted rights to priority in the discovery of ebonite.

The discovery made by Alexander Parkes of Birmingham, in 1846, that soft rubber could be vulcanised by means of a solution of chloride of sulphur in carbon bisulphide, is also, from the chemical

point of view, an original invention. This method of "cold" vulcanisation is still as important as ever, whilst the numerous other processes which were invented during the life of Goodyear's patents have almost entirely lost what importance they ever possessed. Only Hancock's method, which consists in dipping the articles to be vulcanised in a bath of molten sulphur, is still deserving of mention. The other processes are in many instances merely modifications of Goodyear's or Hancock's, so disguised that it might be difficult at first to recognise the circumventing of Goodyear's patent. A favourite method selected for this purpose was that in which vulcanisation is apparently effected by the action of metallic sulphides, but in which it is really the free sulphur present in such sulphides that is the vulcanising agent.

The preparation of soft rubber, according to Charles Goodyear's process, consists in the mechanical admixture with the rubber of from 3 to 15 per cent. of sulphur, the mixture being subsequently heated—in practice under pressure—at a temperature of from 125° to 150° C. The time of "heating," "curing," or "vulcanising" must be varied according to the percentage of sulphur used, the nature of the rubber, the amount and the nature of the other ingredients, the way in which the heat is applied, the form of the article, and, last but not least, according to the technical effect which it is desired to produce. The preparation of ebonite necessitates, on the one hand, the addition of a much higher percentage of sulphur, and, on the other hand, a longer time of curing and higher temperatures. Although all this can be put so simply in a few words on paper, it is just as difficult in practice to find the most suitable conditions in any given case. As a matter of fact, in all factories this particular part of the business is still carried out by empirical methods, resulting from long experience, which are carefully preserved as valuable works-secrets. It is only quite recently that a little attention has been given, side by side with this rule-of-thumb, to theoretical considerations, and that this part of the manufacture has been attacked with scientific assistance. This can, however, scarcely result in a noteworthy revolution in the methods of manufacture. We have certainly gained the knowledge that rubber of any origin combines chemically with sulphur on vulcanisation; that the process is one of simple addition without substitution; that the percentage of sulphur entering into chemical combination with the rubber increases (*a*) with the time of vulcanisation; (*b*) when certain bases, such as litharge, lime, and magnesia are added to the mixing; (*c*) when a good (metallic) conductor of

heat is substituted for a poor one for press plates and moulds; (*d*) when the articles cured are of thin instead of thick rubber, etc., etc. We further know that, contrary to the statement of Clouth,[1] Para rubber vulcanises more rapidly and at lower temperatures than African sorts.

In countries where the decimal system of weights and measures is in use, it is customary to express the amount of sulphur to be added for vulcanisation in percentages on the amount of rubber; *e.g.*, for a soft-rubber mixing with African rubber, 10 to 15 per cent. of the weight of the rubber, or for a hard-rubber mixing 30 to 50 per cent. of its weight may be specified. In order to arrive at comparable figures for the degree of vulcanisation of a rubber, C. O. Weber's proposal has been adopted, according to which the sulphur chemically combined with the rubber hydrocarbon is calculated as a percentage upon the pure rubber substance present. Suppose, for example, that analysis shows pure rubber 50 per cent., combined sulphur 1·5 per cent. Then the so-called "coefficient of vulcanisation" is $\frac{1{\cdot}5 \times 100}{50} = 3$ (per cent. of the pure rubber substance). This vulcanisation coefficient has proved of considerable value in judging samples of vulcanised rubber by analysis, and in controlling the process of vulcanisation.

The properties of rubber undergo an essential alteration on vulcanisation. The extent of the alteration varies, for the most part, directly as the coefficient of vulcanisation. On vulcanisation rubber loses its adhesiveness. As the coefficient of vulcanisation increases, so does the hardness of the rubber, up to the extent of becoming brittle; its resistance to the action of chemicals and solvents increases, its power of absorbing water diminishes, its property of becoming distended by the action of organic solvents becomes less marked. By selecting suitable conditions of vulcanisation, products possessing any degree of elasticity for any given useful purpose can be obtained. Vulcanised rubber is not nearly so sensitive to changes of temperature as is the unvulcanised substance. The colour of vulcanised rubber gradually deepens as the coefficient of vulcanisation increases until the deep black of hard rubber (ebonite) is arrived at. In goods vulcanised under pressure, vulcanisation results in a marked contraction, or decrease in volume, the extent of this increasing with the coefficient of vulcanisation.

Rubber acquires on vulcanisation a different smell from that which it possesses in the raw state; and this is, in many cases

[1] *Gummi, Guttapercha, und Balata*, 1899, p. 123.

sufficiently characteristic to permit of conclusions being drawn as to the kind of raw rubber used. In the case of rubbers which have a bad smell in the raw state, the smell often becomes intensified on vulcanisation ; as, for example, in the case of " Lumps " or " Guayule."

Soft rubber has the reputation of being perfectly waterproof. It is not very well known that soft rubber undergoes a considerable change when subjected to the prolonged action of hot water; it absorbs an appreciable amount of water, becoming much lighter in colour, and suffering a marked diminution in tensile strength. At the same time its power of adhering to fabrics is greatly modified. The thinner the coating of rubber, the more pronounced is the effect of water. This property of soft rubber is utilised, to a limited extent, in the working up of old rubber.

Vulcanisation by Goodyear's method by means of sulphur can only occur at temperatures above that at which the mixture of rubber and sulphur melts. Statements in a contrary sense,[1] to the effect that a thin sheet of unvulcanised rubber containing sulphur can be vulcanised up to a certain point merely by the action of light, have proved, on re-examining the facts, to be incorrect; in no case have such sheets been found to contain a trace of chemically combined sulphur, and they therefore remain completely soluble in benzole. The error has probably arisen from the fact that the sheets in question had to be rendered plastic in the operation of mixing-in the sulphur, but gradually regained, after being kept for a long time, the original physical properties exhibited by the dry unvulcanised rubber before mastication. If pieces of " young " Para rubber about 1 mm. thick be removed from a ball, and allowed to dry gradually, the slices attain in the course of time the appearance and almost the physical properties of vulcanised rubber, and when superficially examined might be judged to be vulcanised. In the case of the unvulcanised sheet containing sulphur the illusion is naturally still more likely to take place, because the addition of sulphur partially destroys the adhesiveness of the rubber. A rubber can only be considered vulcanised if it contain chemically combined sulphur, or sulphur and chlorine. Up to the present no method of reversing the vulcanisation process is known which does not result in the breaking down of the rubber molecule. This point will be more thoroughly dealt with when the subject of " Reclaiming " is considered.

Vulcanisation by means of sulphur generally results in the combination with the rubber of only a portion of the sulphur

[1] *Cf.* Fr. Clouth, *Gummi, Guttapercha, und Balata*, 1899, p. 131.

added. the other portion being merely held in a kind of solution in the rubber, which is in a more or less viscous state at the vulcanising temperature, and crystallising out again on cooling. The changes which occur during the process have been microscopically examined by Pierre Breuil, who has published a number of instructive photo-micrographs of them.[1] The uncombined ("free") sulphur gives rise to the phenomenon of "blooming" or "sulphuring-up," which imparts to the goods on which it occurs a greyish appearance due to a coating of finely-divided sulphur, and which may or may not be desirable from the purchaser's point of view. Sulphuring-up can generally be prevented by using a mixing of a suitable composition. Sometimes the goods are first of all allowed to sulphur-up, the sulphur being afterwards removed by gently heating with solutions of caustic alkalies, or by other means.

As already mentioned more than once, a mixture of plastic rubber and sulphur becomes more or less viscous at the temperature of melting sulphur. This property must be taken into account in the manufacturing processes, where it is necessary to adopt some means of preventing the articles, which have been made to a given shape, from losing that shape when subjected to the vulcanising temperature; this is of especial importance in the case of so-called "open" cured goods. Generally speaking, there is not much risk of the goods actually melting down as a whole, since on the one hand the softening only advances very slowly through the mass of rubber, rubber being a bad conductor of heat, and, on the other hand, the process of vulcanisation tends more and more as it goes on to check anything of the kind; the fear is rather that when the rubber gets soft at the high temperature, the goods will tend to fall out of shape by their own weight if they are not carefully supported in some way. In some kinds of tubing which is cured in the open, this effect of the heat of vulcanisation may be recognised by the fact that the tube has lost its circular cross-section, and become more or less elliptical. This difficulty may be got over by using rubbers which cure quickly, or by the addition, where possible, of appreciable quantities of basic substances which facilitate vulcanisation, such as litharge or magnesia usta, or by increasing the proportion of sulphur in the mixing.

Nothing is yet known with absolute certainty as to how such basic substances as those just mentioned act in facilitating vulcanisation, and fantastic ideas on this subject, as well as on the similar action of metallic sulphides, are therefore in existence

[1] *Le Caoutchouc et la Guttapercha*, ii. 158 and 197.

amongst rubber specialists. We shall not occupy any space in discussing these ideas.

The vulcanisation of thin-walled rubber goods and of lightly proofed fabrics is best carried out by Alexander Parkes' process, in which chloride of sulphur is employed as the vulcanising agent, either in solution or in the form of vapour. In many instances Parkes' cold vulcanisation process is competitive with Hancock's process, in which vulcanisation is carried out in a molten sulphur bath. The practical working of these two processes will be dealt with later on.

It is a very remarkable fact that the processes of vulcanisation which have just been referred to are still carried out in exactly the same way as invented by Goodyear, Hancock, and Parkes respectively. Even with reference to certain details, as, for example, those relating to the use of magnesia usta in hard rubber (*Goodyear*) or to the solvent which it is best to use for chloride of sulphur (*Parkes*), manufacturers have, after making several departures from it, again reverted in almost every instance to the original practice of the inventor. Still it is true that considerable improvements have been made in the course of time in the methods adopted for preserving the form of goods during vulcanisation, and in the methods of applying heat to them.

The Vulcanising Shop.—Having in the last section dealt fully with the nature of vulcanisation, we shall in the present section consider the details of the arrangement of a modern vulcanising shop.

The vulcanising plant forms one of the most important items in rubber-goods manufacture, and it is essential that the shop in which the process is to be carried out should be provided, in every particular, with the most modern and most convenient arrangements that have been devised in the course of the fifty years, roughly speaking, that have elapsed since the rubber industry was founded. As already stated in the introduction (Room D, fig. 1), it is advisable to place the vulcanising plant immediately at the back of the boiler-house, so that the steam-pipes need not be unduly long, an arrangement which tends to minimise condensation in the pipes. Similarly, the shop should be close to the moulding shop, so that the heavier moulds can be moved about with as little difficulty as possible. These two points form, so to speak, the basis of the plan. The building is provided with a span roof so that as much air and light as possible can get in, and so that there are no pillars in the shop to be in the way. It is advisable to have a ridge-turret the

whole length of the shop, provided on both sides with glass jalousies which open very easily, in order to ensure efficient ventilation. A fan driven by an electro-motor is employed to get rid of the steam which escapes on opening the heaters. A plant arranged for a large, well-organised works, and to be put down on the lines of the accompanying plan, would be as follows:—

A mechanically driven traveller for raising and transporting the loads which are to be stacked upon the various heater trolleys runs the whole length and breadth of the vulcanising shop (A, fig. 30). In the adjoining room B are the heaters, ranged along the long side of the shop, with the fronts of the heater doors visible. The heaters themselves are therefore in a separate compartment B in room A; B contains only the heaters, each of which is well insulated. This compartment has a non-conducting top to still further protect the heaters from cooling. We also see here against the wall the heater, about one metre in diameter, which serves to receive the outlet pipes on their way to the condensing tank F.

At a point just before the outlet pipes enter the tank non-return valves are introduced. When steam is blown off from a heater the steam enters the tank, which is filled and kept fed with cold water, where it is condensed, the slight amount of steam produced being able to escape from the condensing tower, which is carried up to a height of about 10 metres, while the condensed steam runs back into the tank. All outlet pipes should be carried into the water to a distance of about two metres. The outlet valves are situated beneath the ends of the heaters in room A. By arranging and building in the heaters in this way all possibility of excessive radiation of heat from the heaters into room A is removed.

In the same room, in front of every heater, are rails on which the vulcanising trolleys run, these being sunk into the ground to a slight depth so that the top of the trolley is level with the main transport rail, which runs the whole length of the vulcanising shop and connects it with the other shops in the factory; this arrangement is such that the loaded trolleys can be run straight from the main rail, over the turntables, on to the heater trolleys, thus doing away with the heavy work of unloading and repacking in chalk. There are four upright heaters in the shop, also of course well-lagged. Two of these are provided with steps leading up to an iron platform surrounding the heater breast-high. Under the main rail track is a tank, used for cooling down the moulds, the whole trolley load being lowered into and hoisted out of the tank by means of a lifting tackle. In a smaller room the goods are packed

in chalk, the air being kept carefully free from dust by artificial ventilation. In this room are also kept various kinds of iron boxes or trays to take the goods, these being put straight on to the trolleys

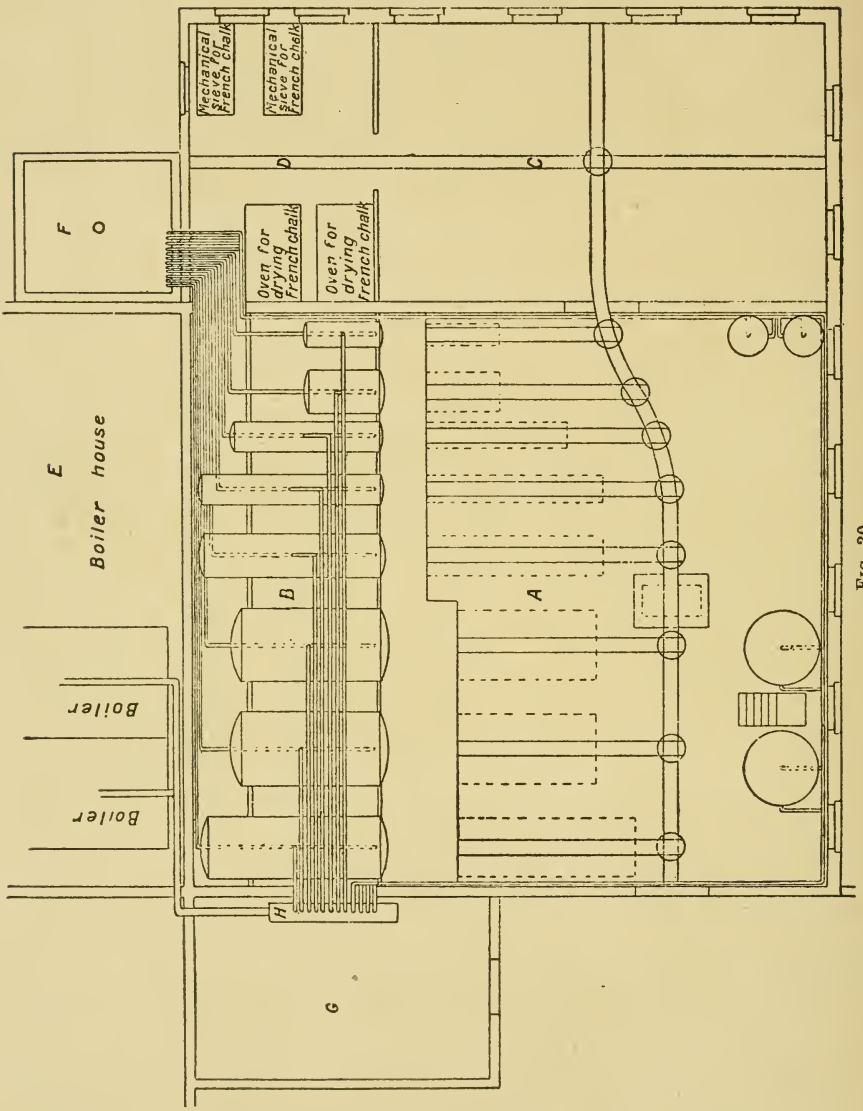


Fig. 30.

and not again unpacked before being cured. They are quite ready to undergo vulcanisation for the necessary length of time, when run into their respective heaters. Another room, D, is used for drying and sifting the chalk used in the vulcanising process. In this room the trolleys are emptied, after vulcanisation, of all goods

which have been cured in chalk. The chalk is then immediately dried in the oven, put through a chain-pump into the revolving sieve, and sifted; it is then ready for further use.

A glance now at the heaters themselves. These should, if possible, be constructed to stand a steam pressure of six atmospheres, and the doors should be designed with a fairly wide flange with a recess in order to give the packing a good firm hold, so that it does not require to be renewed very often. The bolts for closing up the heater door should be fairly strong and thick, so that as few bolts as possible need be used, and the operations of opening and closing the heaters be thus more rapidly carried out. The steam supply to all the heaters is centralised; the steam pipe from which all the supply pipes are taken, and on which are also the inlet valves, manometers, thermometers and water-gauges for every heater, is set up in the control-room G, quite by itself. A similar steam pipe on the other side, fitted with similar apparatus, is used for the press shop. In arranging for the supply of steam to the heaters, and the outlets for condensed water and steam, careful attention must be directed to the pipe system. Under no circumstances should too small a pipe be used, and the outlet pipe should always be larger than the supply pipe. To ensure economical consumption of steam a Bourdon steam-trap may be introduced at the outlet.

With reference to the control-room G, it may be said that it is here that the correct conduct of the vulcanisation rests in the hands of the man in charge. In order that vulcanisation may be successful, this man must perform his duties with exactitude. The steam passes from the boiler-house, through the superheater, where it is dried, to the steam pipe H in the control-room. A steam trap is interposed between the main steam supply pipe and the steam pipe H. Projecting from this we see all the valves, the pipes from which lead to the heaters corresponding to the numbers on the valves. Manometer and thermometer tubes are brought into this room from the heaters, the scales being placed directly above the corresponding valves. In addition, there is an arrangement for introducing a mercury manometer for the purpose of checking the others. Each manometer should be provided with a recording apparatus so that the vulcanisation can be regulated at any moment, and proper control be maintained over the "rise" as well as the steady pressure. The heater having been closed, and the outlet valve adjusted, the man in room A, who should have nothing else to do than attend to the heaters, signals by means of an electric bell

to the foreman in charge of the vulcanisation, in room G, and he sees by the indicator which heater is to be put on. He ascertains the length of the "cure" from the ticket given to him, which shows the quality and nature of the goods to be vulcanised, and by referring to his list of temperatures and times for the various articles. The times of vulcanisation are arranged alphabetically according to qualities, kind of goods, and substance. After the charge of the heater has been entered in the vulcanisation book, and the time of putting on the heater also filled in, these particulars are also marked up on the controlling table in the column corresponding to the heater being used. This table is then hung up; on it is shown which qualities are being vulcanised at the same time. As soon as the steam pressure exceeds the number of atmospheres to which the apparatus has been adjusted the attention of the foreman is called to the fact by the ringing of a bell, if he has not already noticed it on the manometer; by this means the foreman is helped to keep a strict watch, and no prolonged excess of pressure can escape his notice. This whole business consists simply and solely in turning steam on and off the heaters, and in seeing that the manometers and valves are working accurately. When the time of vulcanisation is completed, the valve is shut down, the electric alarm is taken out, and the foreman signals to the man in room A, who sees by the indicator which heater is referred to, to open the outlet valve. On a further signal, when the pressure has dropped to zero, he opens the heater door. The time at which the cure was completed is entered by the foreman in his book, and the department concerned in the further manipulation of the goods is rung up to fetch them away from room A or D.

The above scheme provides for subdivision of labour, and does away with the opportunities which otherwise occur for the man in charge of putting on and regulating the heater to concern himself with other jobs. In his separate room he has nothing to do but look after the valves and manometers, while the man in room A has only to see to the opening and closing of the heaters. The men employed in these two rooms are, under this arrangement, not troubled by dust, or by intense heat, which would tend to distract their attention from their duties.

It has already been stated that the chief things to be sought after in vulcanisation are the use of dry steam and the maintaining of the proper temperature, the pressure of the steam not coming into account as far as the cure itself is concerned. Pressure is, however, by no means an unimportant factor.

The heater shown in fig. 31 is the ordinary type of simple heater. As a rule the steam is not led in from a single opening, but is distributed by means of a spray-pipe, which is laid along the bottom of the heater; this pipe is closed at the end and provided with small holes at intervals along its walls. The pipe is covered by a perforated iron plate. Considerable advantages follow from the use of a jacketed heater for vulcanisation, not so much for hot-air vulcanisation as for getting the outer jacket hot before letting steam into the interior of the heater, and so to a large extent

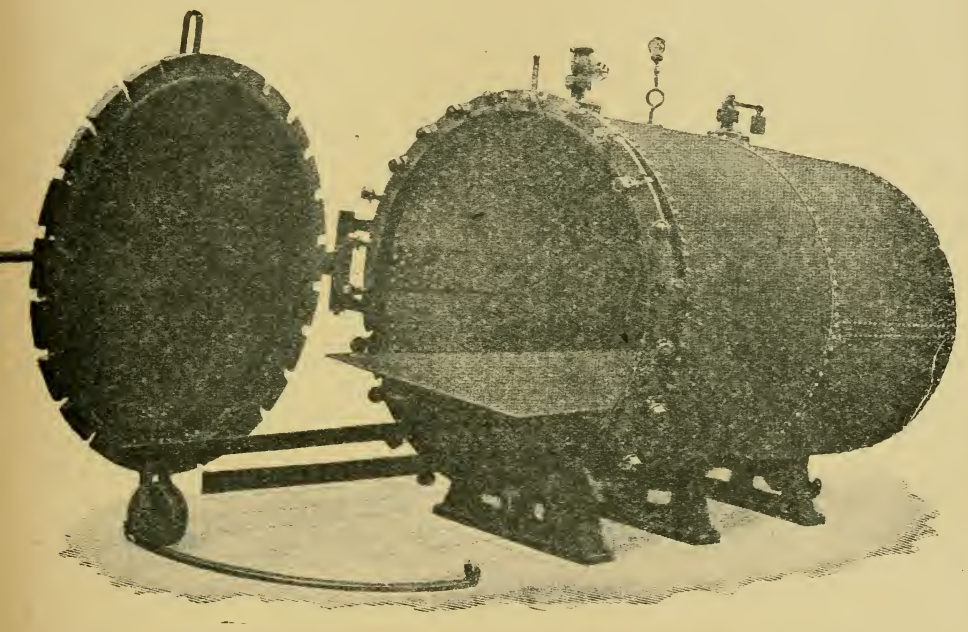


Fig. 31.

preventing condensation and maintaining a uniform temperature. To achieve this end the pressure in the outer jacket must be half an atmosphere above that inside the heater itself.

The dimensions of single heaters are very various, and depend upon those of the goods to be cured in them. Heaters from 80 cm. to 3 metres in diameter are used; for special purposes, indeed, such as cable manufacture, the diameter is sometimes as great as $3\frac{1}{2}$ metres; the length or height of the heater varies from 1 metre to 5 metres. For hose, heaters are used which are as much as 51 metres long, with a standard diameter of 85 cm. The trolley is in this case provided with shelves, and is run in and out automatically. By this means a considerable economy is effected, for in order to

move such a trolley some eight to ten men were always required, in addition to which the uneven, jerky, one-sided pulling often resulted either in the trolley being run off the rails, or in the rails, which lie on segments inside the heater, being jolted out of position. On the other hand, the operation can be carried out mechanically with great smoothness in from two to three minutes, with the aid of a single man. To ensure an even distribution of steam, at least

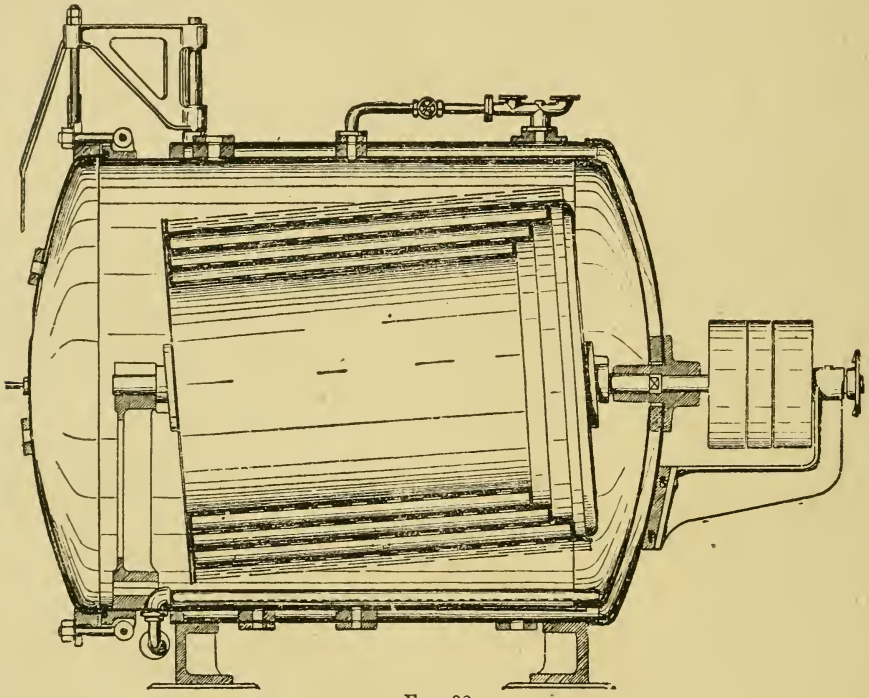


Fig. 32.

four inlets should be provided; the introduction of the steam is in principle the same as in the other heaters.

In all ordinary heaters, without exception, there is a tendency to the formation of steam banks; to do away with this, and to ensure getting steam at a uniform temperature in every part of the heater, a new apparatus has been constructed (fig. 32). This new autoclave (Heil's patent) contains a drum, which revolves slowly backwards and forwards, and on which the goods to be vulcanised are wrapped. The angle at which the drum is inclined, together with its backward and forward motion, results in the complete uniformity of the steam, and prevents the accumulation of wet steam in the lower part of the heater. All surfaces of the goods

are therefore subjected to a uniform vulcanising temperature, and a uniform combination of sulphur is brought about throughout, a fact which has been established experimentally by determinations of the coefficient of vulcanisation in the different layers of the vulcanised goods. In connection with the drum-movement is the innovation of the blow-off cock for condensed water, the circulation of steam being also regulated by this, and overheating by too

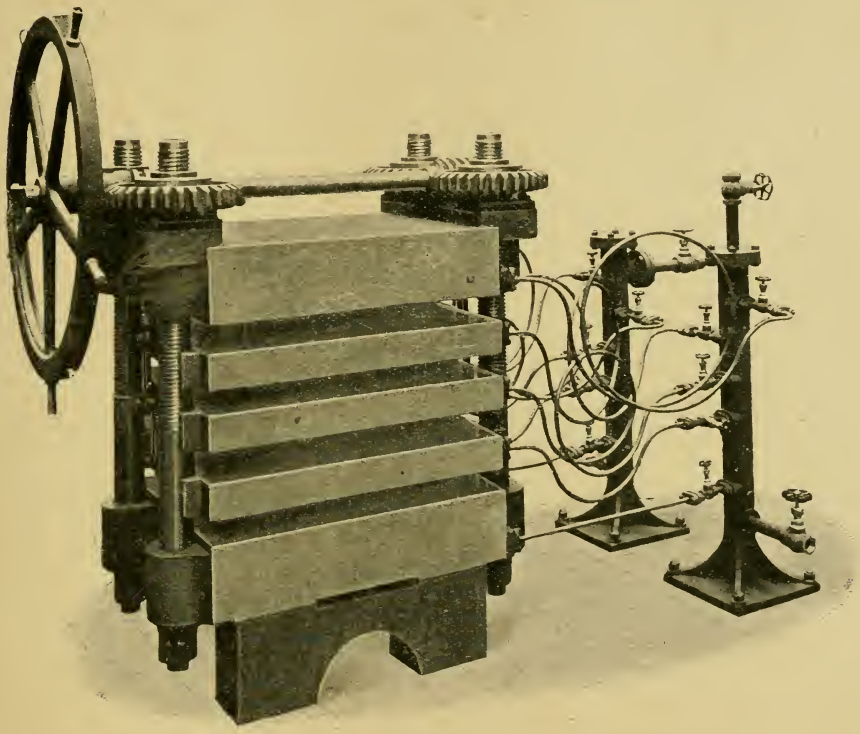


Fig. 33.

sudden an increase in pressure prevented. A complete description of this apparatus has already been published.[1]

The Press Shop.—This department is housed in room F (fig. 1), and separated from the boiler-house by the moulding shop. Vulcanisation is here carried out in steam-heated presses. Steam is turned on, and manometers controlled from the second steam pipe in control-room G, in exactly the same way as described in the case of the heaters.

The vulcanising press consists of upper and lower hollow plates, heated by steam and capable of standing pressures up to five atmos-

[1] *Gummi-Zeitung*, 1905, xix. p. 1027.

pheres. The plates are traversed by heating channels so arranged that the condensed water can easily run away, a point of very great importance, especially in the case of the upper plate. The upper plate is worked by central screws, by which the plate is raised and

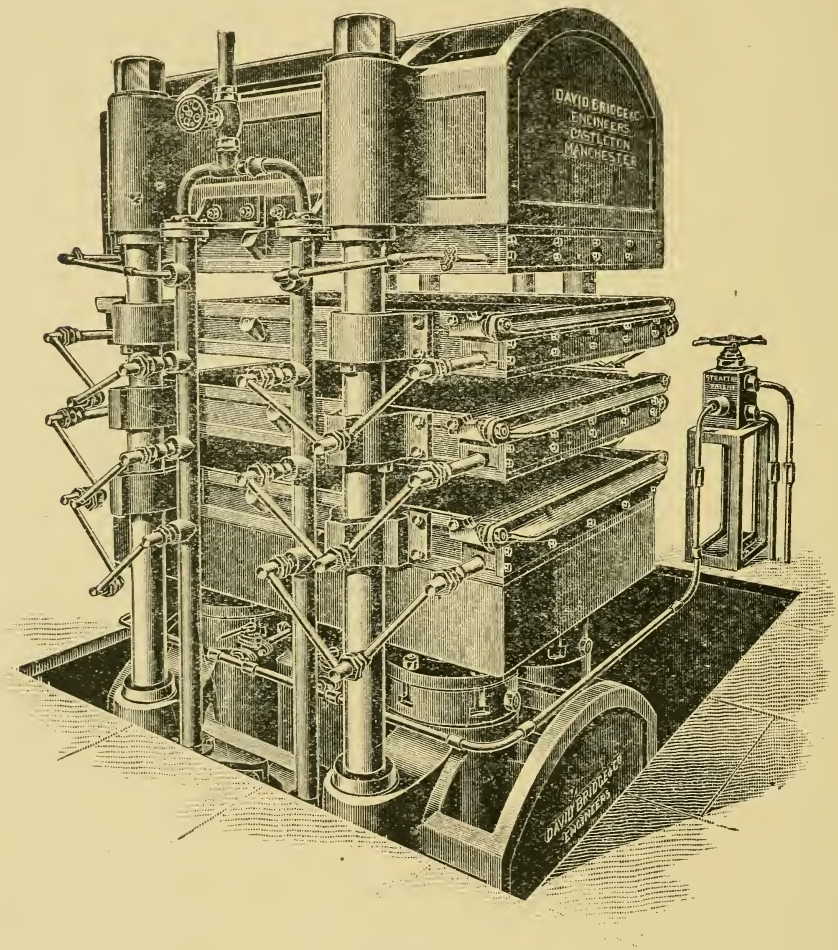


Fig. 34.

lowered. The lower plate is firmly fixed upon the iron base and is jointed to the top cross-piece, through which the spindle passes, by means of standards which serve as guides.

Larger presses are constructed on the principle illustrated in fig. 33. Latterly, presses worked by hydraulic pressure have been given a preference over others, since more can obviously be accomplished with them. For an up-to-date factory the following

sizes are necessary, in addition to a few small screw-presses:—A hydraulic press with plates 60 cm. wide for moulded goods; and for sheet and similar goods, which are pressed on moulding

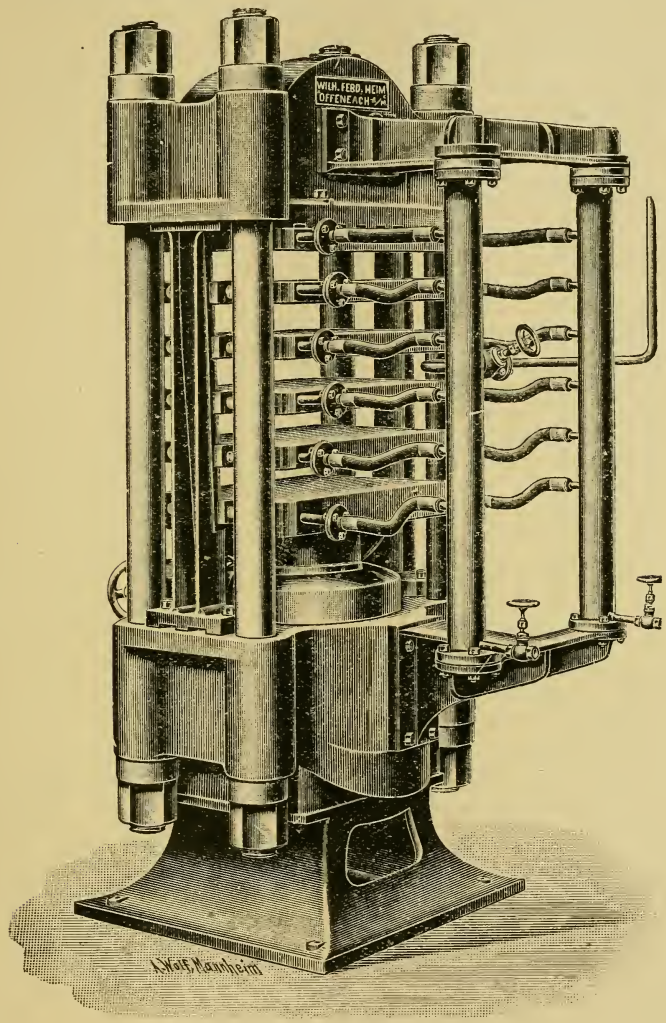


Fig. 35.

plates, an 80 cm. press, with four to six heating-plates, so that from three to five vulcanisations can be carried out in it at the same time; such presses are shown in figs. 34 and 35. For larger sheets a press with 120 cm. plates is required. All these presses are furnished with a single pressure cylinder, and work at a water pressure of 250 atmospheres or 20 kilograms per

sq. cm. For vulcanising press-plates, sieve-plates, etc., presses

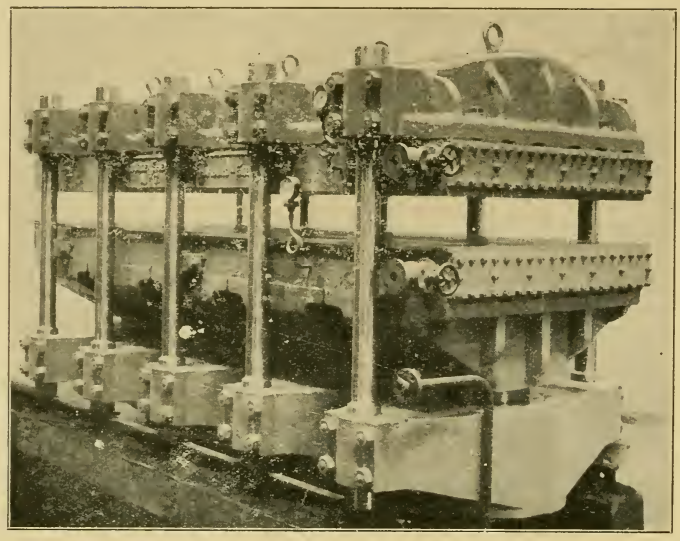


Fig. 36.

4 metres long by 1½ metre wide, and provided with five pressure cylinders, are necessary; a press of this description is shown in

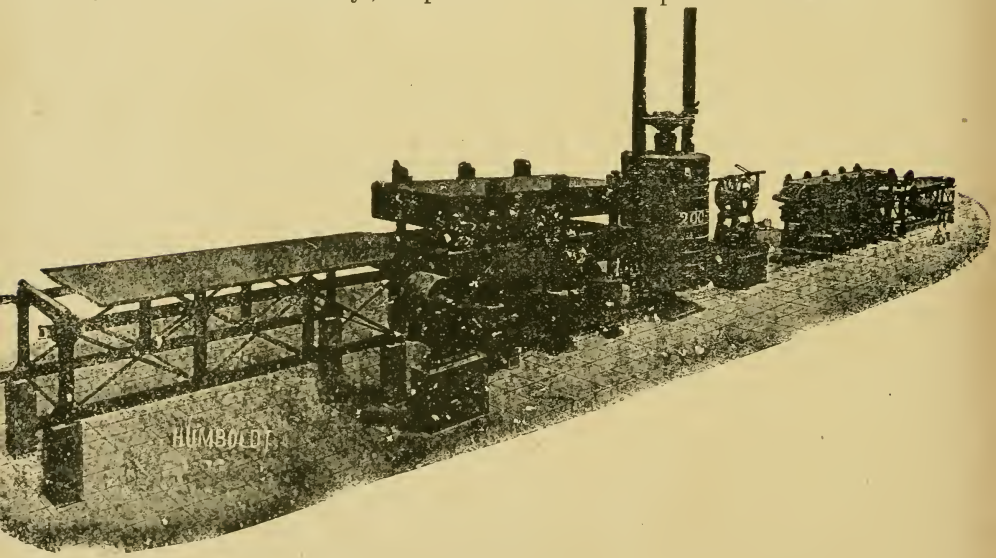


Fig. 37.

fig. 36. A draw-plate for withdrawing the sheet, as supplied with the presses already described, is, in this case, a prime necessity.

Whereas the smaller presses are worked entirely by accumulators, in the case of the two last mentioned a pump (fig. 38) must be used to provide the pressure, accumulators being also used, both in this case and in the case of the presses still to be described, in order to compensate for any variation of pressure in the individual pressure cylinders, which are all in communication with one another at the pump. For rubber belting a press is used which

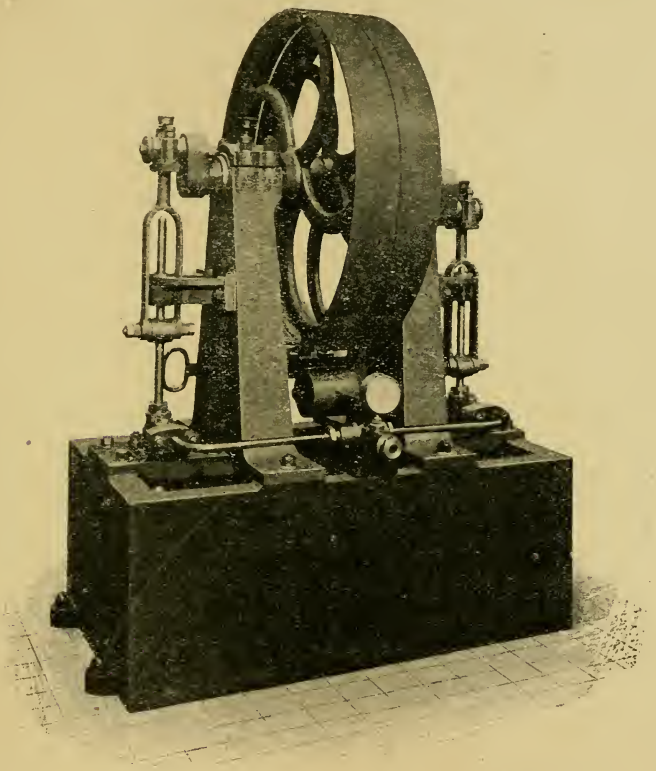


Fig. 38.

measures as much as 7 metres long by 1 metre wide, and which, as shown in fig. 39, has attached to it a separate hydraulic stretching apparatus. For billiard-strip, deckle-straps and similar articles which are vulcanised in moulds, a press about 2 metres long and 60 cm. wide is used. The two last-mentioned presses have no draw-plate connected with them; the belts or the moulds are introduced immediately under the press-plate. In the construction of hydraulic presses the steam-plates, by which the pressure is applied to the articles, and which must be absolutely smooth and

true, should not be cast in one piece with the top plate, but should be mounted separately, and insulated from it by means of asbestos. In the large presses the top-casting is preferably built up of separate parts, and not in one single piece as in fig. 37, for with this form the plate may easily be fractured, when heated and under pressure, owing to uneven expansion. The upper and lower plates are independently heated, each being provided with a separate pressure gauge. In order to cool down the plates rapidly, after steam has been blown off, an apparatus may also be used by means of which a current of cold air is passed into them through a pipe from an exhauster. The goods to be vulcanised are built up on the press-table, the proper size being secured and the necessary support given

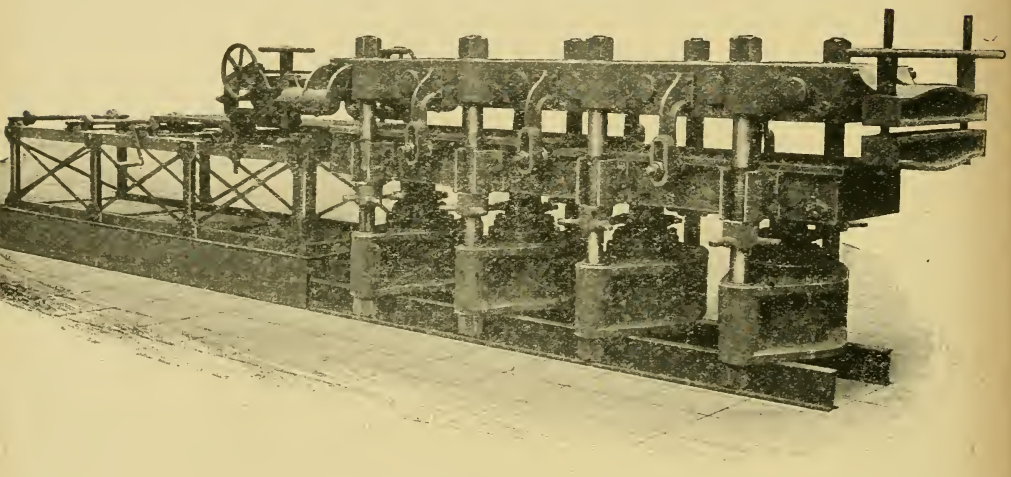


Fig. 39.

to the sheet by means of accurately planed square-iron bars. On top of the article is placed a thin enamelled steel sheet about $\frac{5}{10}$ mm. thick, which lies smoothly under the press and gives to the rubber sheet a fine polished upper surface. It should also be mentioned that the draw-plate should be of sufficient size, in order that when it is under the press its ends may project to a distance of about 25 cm., so that in the case of long articles, such as mats, the ends of the separate pieces may be easily joined together and cured up into one piece. In the large presses, particularly those used for belting, the side rods should be adapted for easy removal, so that endless belts and conveyors may, if necessary, be put in from the side. The large belt presses with an intermediate plate are not to be recommended, since, owing to the length of the press, an uneven strain is produced in it by expansion.

Plant for Sulphur-bath Vulcanisation.—The apparatus which is used for the vulcanisation of cut-sheet or dipped goods by heating in molten sulphur, consists of a wrought-iron heating-vessel, about 1 metre in depth and 1½ metres in length and breadth. The sulphur-bath may be heated by means of steam or hot gases, or by direct firing. In putting up a direct-firing plant, the greatest care must be taken with the setting of the heating-vessel, only the best material being employed. The arch of the furnace, with which the flame comes into direct contact, as well as the fire-bridge, are made of good firebrick held together by means of the best chamotte powder. The adjacent faces of the bricks are carefully made smooth, so that only a very thin layer of the chamotte is necessary to cement them together. By this means a very strong joint is made, and the bricks cannot get loose and drop out.

The bottom of the heating-vessel rests on an arch, a course of bricks which protects it from the direct heat of the flame. The hot gases pass under the vessel, then upwards and along one side of it, round the back and along the other side, and thence are led away to the chimney. The outside walls must be well insulated and plastered. The mass of sulphur can also be heated by steam, but only if superheated, or the hot gases from the furnace of a steam boiler, as they pass from the flue to the chimney, may be utilised for the purpose. Direct firing is preferred in many factories. To hinder the formation of sulphide of iron by the action of the sulphur on the iron of the heating-vessel, which results in the formation of an incrustation on the bottom of the latter, and tends to destroy it, the inner surface of the heater is periodically covered with lead. The temperature of the sulphur bath is measured by means of thermometers, protected by iron tubes, and with their bulbs reaching to about the middle of the heater, the scales being at a convenient height above the top. The most convenient form of thermometer to use is one which can be set to the desired temperature, and so arranged that when that temperature is exceeded a bell is rung to warn the man in charge that it is necessary to look to the fire. Soft rubber articles are generally vulcanised at 135° C., cut-sheet goods at 135° to 140° C., while for hard-rubber shaped objects, temperatures as high as 160° C. can be employed.

The sulphur vapours given off during the heating are carried away by a powerful exhauster. To this end a metal hood is fixed over the heating-vessel, galvanised iron being the most suitable material to use. The front and back walls of this can be raised to

a height of about 1 metre above the heater, where they remain while work is going on. The hood tapers away towards the top like a funnel, and opens into a pipe which leads to the exhauster. This pipe must not be too small in diameter. To the exit side of the exhauster a tube is attached which leads into the workshop and opens into a "Cyclone" dust-collector, which can either be stood on the ground or suspended. In this way the air is freed from the particles of sulphur. The air passes out through a side pipe, whilst the sulphur dust is compressed on to the walls of the cyclone, and is drawn off below into a receptacle.

As already mentioned, this method of vulcanisation is chiefly used for cut-sheet goods. Flat articles are simply laid in the sulphur bath and stirred about with a wooden stick; they are examined at frequent intervals; the larger articles are also frequently turned over, so that every part may be equally acted upon by the sulphur, and one side not become more highly vulcanised than the other.

The vulcanisation of teats, which have a curved surface, is carried out in the following way. The teats are taken off the moulds and stood in shallow iron trays, the depth of which is, however, a few centimetres greater than the length of the teats. The bottom of this tray is perforated with a large number of holes, each 5 to 7 mm. in diameter. Over each of these holes a teat is placed, and when all the teats have been placed in the tray, sulphur is poured over them. On cooling, the teats become firmly fixed to the iron sheet, do not fall out when the tray is inverted, and do not bend out of shape when the tray is immersed in the molten sulphur. In lowering the tray into the sulphur, the closed ends of the teats are put in first, the bottom of the tray last. The tendency of the teats to rise to the surface on account of their low specific gvavity, is checked by their pressure against the bottom of the tray, which keeps them in their original positions. The holes in the bottom of the tray allow the air in the teats to escape as they sink below the surface of the sulphur. When vulcanisation is completed the iron tray is carefully lifted out of the sulphur, whereupon the teats immediately rise to the surface, from which they are ladled off. They are then shaken up in a cloth, and well rubbed to prevent their sticking together, which they would otherwise do, thus causing difficulties in the subsequent treatment. The articles are now freed from adhering sulphur by heating in soda solution. Various other articles made from cut-sheet—urinals, for example—can also be vulcanised on sheet-iron moulds. In this case the small end of the

mould must be put downwards into the sulphur, otherwise the article would leave the mould and rise to the surface.

This method of vulcanisation, in addition to being used for cut-sheet goods, is also specially suitable for soft or hard-rubber goods which have to be vulcanised in moulds, and particularly for bulk-production. The moulds are generally suspended from iron rods laid across the tops of the heating-vessels.

In this process the waste of time involved in the opening and closing of the heater, which is necessary in vulcanisation by means of steam, is done away with; and secondly, one has not to wait until the requisite number of moulds to fill a heater are ready before beginning the cure, but a single rod of moulds can be suspended in the sulphur as soon as it is ready, and the process repeated until the bath is full. By careful management it is possible so to arrange things that the first rod of moulds is fully vulcanised, and can be removed from the bath as soon as the last rod has been provided with moulds. With the same number of moulds it is possible by this method to vulcanise 40 per cent. more articles in a given time than by heating in steam. A further advantage possessed by these goods over steam-cured goods is that they exhibit a velvety coating on the surface, and that they are much more easily detached from the iron moulds than goods of the same qualities vulcanised in steam.

It is of great importance in the sulphur-bath process to keep the sulphur constantly at the right temperature; fluctuations in temperature seriously detract from the usefulness of the method. As soon as the sulphur gets overheated it catches fire, in which event the heating-vessel should be immediately closed to the air by lowering the hood.

The scum which collects on the surface of the sulphur during use should be removed at intervals with the ladle; fresh sulphur must also be added from time to time, to make up for loss by evaporation. For this purpose ordinary flowers of sulphur may be used.

The bath should also be kept hot during the night, otherwise the sulphur would cool down too rapidly and solidify, which means great waste of time, for the cold sulphur can only be heated up very gradually.

Consideration of the Vulcanisation of Proofed Fabrics by the Cold and the Hot Processes respectively.—It may be repeated that two methods of vulcanisation have to be taken into consideration, namely, that carried out at high temperatures in which elementary

sulphur is the vulcanising agent employed; and in the second place, that carried out at ordinary temperatures by means of chloride of sulphur. The former method can be applied quite generally, but is comparatively troublesome, and necessitates, in most instances, more or less complicated arrangements. On the other hand, vulcanisation by means of chloride of sulphur cannot be adopted generally, since it does not permit of articles of above a certain (comparatively small) thickness being vulcanised right through. In the case of very thin sheet-rubber, however, its employment offers advantages which render its continued use in rubber manufacture a certainty, although the view is often held that cold-cured goods are not as durable as others. This view is not, however, correct in a general sense, even though goods which when vulcanised by heat have turned out perfect may not give satisfactory results on cold vulcanisation. The cause of the failure is to be sought, in this instance, not in the method, but in the conditions under which it is applied, such, for example, as the use in the mixing of ingredients with which chloride of sulphur does not agree.

When price and output have to be considered, cold vulcanisation offers very special advantages in the case of certain materials, and it cannot fail to be of interest to bring forward a few important points which very often remain unobserved, and lead to bad results. The most important point to be borne in mind in connection with the cold process is the great reactivity of chloride of sulphur towards other substances than rubber. Mixings which contain red-lead, litharge, zinc oxide or calcium hydrate, must remain absolutely out of the question as far as cold vulcanisation is concerned, for they are bound to give bad results under all circumstances.

The interaction between sulphur chloride and rubber proceeds quantitatively even when comparatively large proportions of chloride of sulphur—far exceeding actual requirements—are used. The rate at which the addition of chloride of sulphur to rubber takes place depends, however, entirely upon the concentration of the sulphur chloride.

Vulcanisation by means of pure chloride of sulphur in the liquid form is therefore not possible in practice. It would result in the conversion of the whole of the rubber coating into the horny chlorosulphide ($C_{10}H_{16}S_2Cl_2$), and in the consequent total destruction of the rubber.

On the other hand, in vulcanisation by means of the pure chloride in the form of vapour this danger is entirely avoided, but only the surface of the rubber is cured, the vapour not penetrating

to the inner layers. The only remaining method is that involving the use of chloride of sulphur in solution, and this is the one in most general use. The suitability of a given solvent for purposes of vulcanisation depends upon its fulfilling the following conditions :—

1. The solvent must be chemically indifferent towards chloride of sulphur.
2. Its boiling-point should not be above 100° C.
3. It should have a constant boiling-point.
4. It should be a good solvent for rubber.

The first of these conditions is an obvious one, and the second is quite comprehensible, if it be remembered that the process of cold vulcanisation is a continuous one. With reference to the third condition, the vulcanising liquor is contained in an open vessel, and must preserve a constant level; in the course of the day evaporation of the vulcanising solution occurs at the comparatively high temperature of the workshop, and if the solvent be not a simple substance, but a mixture of different compounds with different boiling-points, evaporation takes place chiefly amongst the lower boiling portions of the solvent. This in itself would be of no importance, but in most cases it will lead to a more or less considerable change in the surface tension of the solution, generally in the direction of an increase. The result of this is that a larger quantity of the solution is transferred, by the roller revolving in it, to a unit area of the surface of the material. This results in a harder vulcanisation than was anticipated, and may go so far as to actually damage the article which is being cured. This happens when petroleum-ether is used as a solvent for the chloride of sulphur. In some large-scale experiments having for their object the introduction of this solvent in place of carbon bisulphide, signs of over-vulcanisation became evident after a short interval, and gradually grew more pronounced. The reason of this is not the increasing concentration of the vulcanising liquor (of course this also takes place in a simple solvent, but is easily compensated for), but the increase in surface tension which accompanies the rise in boiling-point.

The fourth condition is capable of an equally simple explanation; it has its basis in the fact that in consequence of the high velocity of the reaction between chloride of sulphur and rubber it is a very difficult matter to vulcanise a piece of rubber uniformly right through. Now the velocity of reaction is very much diminished by the presence of the solvent and diluent, and therefore,

if the solvent fulfils the fourth condition, the solution of chloride of sulphur will penetrate into the rubber at a greater speed than that with which interaction between the chloride of sulphur and the rubber takes place at the surface of the latter, so that uniform vulcanisation right through the layer of rubber is dependent upon the suitable dilution of the chloride of sulphur. If, however, the boiling-point of the solvent be too low, it evaporates too rapidly, and only a relatively slight penetration of the layer of rubber can take place. In addition to this the speed of the reaction between rubber and chloride is increased to such a degree by the rapidly increasing concentration which occurs when such a solvent is used, that uniform vulcanisation can no longer be expected. A solvent with a very low boiling-point, and which therefore evaporates very rapidly, produces a more or less considerable fall in the temperature of the surface from which it is evaporating, inevitably resulting in the deposition of moisture upon it if the air is at all moist. Owing to this deposition of moisture a decomposition of the chloride of sulphur goes on side by side with the vulcanising action. This decomposition is not, however, of the simple kind it is ordinarily assumed to be. It is a fact that if the action occurs on a piece of rubber, and the products of decomposition are not at once removed, evil-smelling products are formed, which are very difficult to get rid of afterwards; care must therefore be taken to rigorously exclude all moisture. That carbon bisulphide is still not the most suitable of diluents is indubitably clear from the foregoing remarks; it has, however, been found, generally, that no other solvent, such, for example, as benzine, benzole, or petroleum spirit, is equal to it. Carbon tetrachloride is at present too costly to be considered, benzine has not a constant boiling-point, and has not sufficient penetrating power, the result of which is that the inner layers do not get cured. Benzole could only be used in its purest form as a diluent for chloride of sulphur, but its price is then too high, and it causes the rubber to swell up too much.

In making up the vulcanising liquor care must be taken to see that the chloride of sulphur and the carbon bisulphide are free from water, since water decomposes the chloride, forming hydrochloric acid and setting sulphur free. The percentage of chloride of sulphur is regulated according to the rubber mixing used, the thickness of the rubber, and the kind of raw rubber employed. Strictly speaking, pure rubber mixings should require a stronger liquor than those containing a high proportion of fillers. Different solutions need not, however, be made up for the better qualities, pro-

vided the same brands of raw rubber are used, for a material proofed with pure rubber solution takes up appreciably more of the liquor from the roller than others which are loaded with mineral ingredients, this being due to the fact that the pure rubber swells up to a greater extent and also more quickly. The proofed material is in contact with the liquor for only a very short time, and during this time takes up as much as its content of pure rubber will allow, and that is clearly proportionately less with lower qualities.

In the following table are recorded the results of experiments made with different raw rubbers, both alone and when mixed with substitutes and other fillers.

Results of Vulcanisation.

Nature of the Mixing used for Proofing.	Vulcanising Liquor.				
	1 : 40	1 : 34	1 : 30	1 : 20	Elasticity.
Pure Para	tacky	soft	good	hard	5
,, Ceara	soft	good	firm	brittle	4·65
,, Madagascar	sticky	tacky	soft	good	3·6
,, Mozambique	soft	pretty good	good	hard	4·4
,, Kassai	sticky	tacky	good	brittle	4·7
,, Congo	very sticky	pretty good	firm	cracked	4·4
,, Cameroon	very sticky	good	hard	...	1·8
Para with substitute	...	tacky	...	good	4·4
Ceara ,, ,,	soft	...	pretty good	firm	4·0
Congo ,, ,,	...	sticky	soft	good	3·8
Para with 20 per cent. other ingredients	soft	good	hard	brittle	3·0
Ceara with 20 per cent. other ingredients.	almost good	firm	cracked	brittle	1·7
Congo with 20 per cent. other ingredients.	almost good	good	bad	brittle	1·9
Para with 10 per cent. substitute and 20 per cent. other ingredients.	soft	too flabby	almost good	stiff	2·9
Ceara with 10 per cent. substitute and 20 per cent. other ingredients.	soft	good	firm	hard	2·0
Congo with 10 per cent. substitute and 20 per cent. other ingredients.	soft	good	brittle	...	2·1
Congo with 50 per cent. other ingredients.	soft—	good	firm to hard	cracked	3·5
Columbian with 50 per cent. other ingredients.	...	...	...	...	3·9
Para with 50 per cent. other ingredients	good	brittle	hard	...	4·0
Cameroon with 50 per cent. other ingredients.	good	hard	...	...	1·7
Congo with 10 per cent. of Pontianac added.	brittle	...	...	...	...

If too dilute a vulcanising liquor be employed tacky products are obtained, which in course of time, often even in a few hours, decompose.

Results of J. Minder's Experiments on Cold Vulcanisation.—Sample pieces of rubber were vulcanised in liquor of the strengths indicated in the following table, and were then heated in steam under a pressure of three atmospheres for the length of time indicated.

The symbols used in the table have the following significance: — good, O tacky, | soft, × brittle, and — hard.

Strength of Liquor.	Hours.											
	½	1	1½	2	2½	3	3½	4	4½	5	5½	6
1 : 100	—	O	|	|	|	|	|	|	|	|	|	|
2 : 100	—	—	O	|	|	|	|	|	|	|	|	|
3 : 100	—	—	—	O	|	|	|	|	|	|	×	×
4 : 100	—	—	—	—	O	|	|	|	|	×	×	×
5 : 100	—	—	—	—	O	|	|	|	×	×	×	×
6 : 100	—	—	—	—	—	O	|	×	×	×	×	×
7 : 100	—	—	—	—	—	—	O	×	×	×	×	—
8 : 100	—	—	—	—	—	O	×	×	×	×	—	—
9 : 100	—	—	—	—	O	×	×	×	×	—	—	—
10 : 100	—	—	—	O	×	×	×	×	—	—	—	—
11 : 100	—	O	×	×	×	×	×	—	—	—	—	—
12 : 100	—	O	×	×	×	—	—	—	—	—	—	—

When we come to consider more closely the vulcanisation of doubled fabrics, cold vulcanisation has to give way to the hot process. As already mentioned, doubled waterproof cloth consists of upper- and under-cloth. The latter takes the place of the lining. Both cloths are proofed, the upper one so as to be quite waterproof, while the under one is only coated to such a thickness as will enable it to stick well. In carrying out the vulcanisation the rubber coating of the upper-cloth is vulcanised, and then united with the unvulcanised under-cloth on the doubling calenders. The solvent has not undergone such complete evaporation at this stage as to interfere with the adhesive properties of the rubber coating, and, on the other hand, the process of vulcanisation is not complete before the two cloths are doubled together, so that a perfect union of them is effected between the rollers.

The vulcanising liquor is transferred to the under-cloth to a

sufficient extent for both cloths to become thoroughly vulcanised. It would not be correct to vulcanise both cloths first and then double them together, since the under-cloth has not a waterproof coating, and the liquor would penetrate through the thin adhesive layer of rubber to the cloth, and might spoil the colour and give rise to spots. One great drawback to cold-cured doubled cloths is the "rustling" and the lack of suppleness in the feel of the finished stuff.

It is not practicable to vulcanise coloured cloths in steam, since they are considerably damaged in the process. The most satisfactory method of vulcanisation for these materials is by means of hot air in vulcanising stoves. Hot-air vulcanisation on drums in jacketed heaters is not to be thought of, for it must be remembered that the cloth is an exceedingly poor conductor of heat, and when it is wrapped round a drum to a considerable thickness, it is only the innermost layers, next the sheet-iron drum, and the outermost layers, which become vulcanised, or these become more highly vulcanised than the intermediate layers; for as soon as equilibrium of pressure is reached in these intermediate layers, all hot-air circulation is at an end. To get over this difficulty it would be necessary to interpose a sheet of tinfoil, equal in length to the cloth between the layers, as is done in America, so as to conduct the heat into the body of the stuff, and so bring about uniform vulcanisation of the whole length. Little benefit would result from the introduction of hot air under pressure into the stove, for the cloth is a bad conductor, and once the air-pressure becomes equalised throughout, things come to a standstill again.

The best method of vulcanisation involves the use of heating chambers, of which the internal arrangements are similar to those illustrated in fig. 40; the proofed doubled cloth passes direct from the spreading machine or calenders (fig. 41), through the heating chamber, which is kept supplied with hot air, and in which the air is kept in continual circulation. In this way an absolutely uniform vulcanisation can be effected; the chamber is completely enclosed, and the cloth in passing through it makes a number of convolutions, which can be increased or decreased at will according to the length of cure required by the rubber; the time of cure is the time which elapses between the entry of the cloth into the chamber and its exit, the temperature being that of the hot air.

Waterproof fabrics, coated on one side only, and on the inner surface of which higher demands are made, are best cured by the cold process, since it is not so easy, and indeed frequently almost

impossible, to ornament the proofed surface when the goods are cured by the hot-air process; moreover, the number of ornamenting agents that can be used is smaller, and it may, indeed, be said that a given process of ornamentation gives incomparably finer effects with the cold cure than with the hot. The simplest method of imparting to the rubber surface a pleasing appearance consists, unquestionably, in spreading as thin a layer of rubber as possible, and using perfectly transparent solution without, therefore, any pigmentary substances. The pattern of the cloth, toned down by the colour of the rubber, is then visible through the transparent

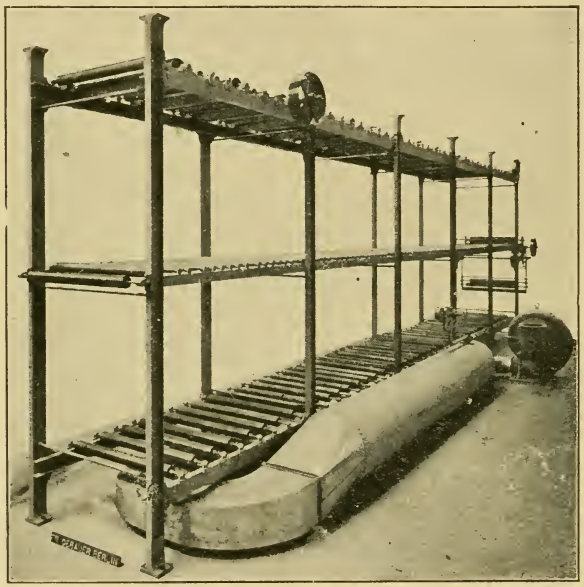


Fig. 40.

layer of rubber, to which the well-known "velvet" finish has been given before vulcanisation, by means of starch. Very good results are obtained by this process when cold vulcanisation is employed, particularly on cloths with floral or fancy designs. By the use of dyes soluble in benzole any desired colour can be given to the rubber, modified, of course, by the colour of the cloth underneath. The use of this process is, however, conditional on the employment of cold vulcanisation, for apart from the difficulty of preserving the transparency of the rubber-layer when it is vulcanised by heat, the colourings produced would be destroyed, almost without exception, by the hot process. One process for the ornamentation of proofings must be regarded as particularly successful; this depends upon

the action of chloride of sulphur on the coating of starch covering the tacky layer of rubber. The mode of operation is based upon the observation that chloride of sulphur converts the powdery coating of starch into a semi-transparent layer with a silky gloss, and upon the further fact that whilst a double treatment of the rubber coating to be vulcanised with a 3 per cent. or a 2 per cent.

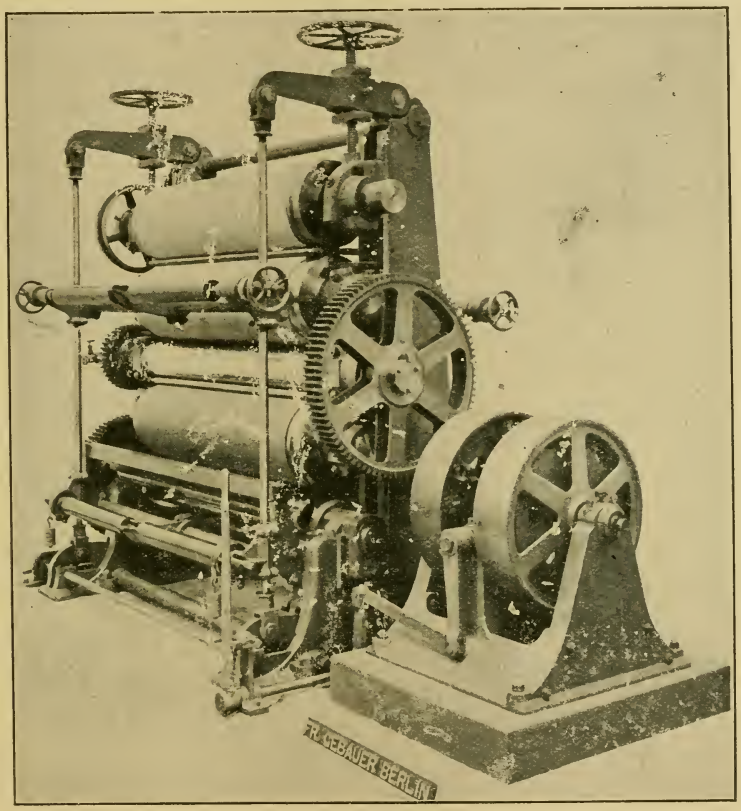


Fig. 41.

solution of chloride of sulphur is equivalent to a single vulcanisation with a 5·5 per cent. solution, the starch is in the former case much more transparent than in the latter. In fact, the 5 per cent. solution has not a much greater effect upon the starch than the 3 per cent. solution, and the result is practically the same if the first solution is a 4 per cent. and the second a $1\frac{1}{2}$ per cent., or conversely; this behaviour is utilised for purposes of ornamentation in the following manner:—

The rubber-coated material is first treated with potato starch,

that which does not adhere being carefully removed by means of a brushing machine. The rubber is then vulcanised by means of a 3 per cent. solution of chloride of sulphur, passing on to a second vulcanising machine in which a 1½ per cent. solution is employed. The vulcanising roller of this, however, is not smooth like that of the first, but is turned down to a depth of about 1 cm. in those places where it is desired that the liquor should not be carried up by it. These grooves are arranged in regular groupings with respect to breadth and axial distance, and the vulcanising liquor is therefore taken up from the roller in the form of bands, in this method of working. The result is that wherever the rubber has been in contact with chloride of sulphur twice, the starch becomes much more transparent than in those places which have been only once wetted by the liquor. The surface is therefore much less glossy in the latter places than in the former, which are almost transparent and colourless, but have a fine silky gloss. The most diverse effects can be produced in this way, and can be heightened and modified by the use of rubbers coloured by suitable pigments. The only difficulty in connection with this method lies in the circumstance that up to the present it has not been found possible to produce other than striped patterns, since the vulcanising liquor will not be carried up properly by engraved or elaborately turned rollers. A very good effect is, however, produced by cutting the bands on the vulcanising roller narrow, and very slightly waved axially. This roller is then used for the first vulcanisation. For the second vulcanisation, on the other hand, a roller is used which is also provided with narrow bands, but slightly inclined to the axis of the roller; in this way a highly satisfactory "moiré" effect is produced.

The cold vulcanisation process is particularly well adapted to the production of coloured effects, since delicate colours can be employed which would be destroyed by hot vulcanisation. In particular, oil-soluble aniline and resinate colours may be used. The lakes of coal-tar dyes are particularly well adapted for this purpose. Great circumspection is necessary in the selection of these, since many of them are not fast to water. The lakes of the polysulphuretted azo-dyestuffs in particular are defective in this respect, as are also those of the crocëins. The lakes of the basic dyes give good results as regards fastness to water, as sulphonated colour bases; also the amido-azo colours. The most suitable base for these lakes is a molecular mixture of aluminium hydrate and barium sulphate, obtained by precipitating aluminium sulphate with soda and with

barium chloride. The basic colours are fixed upon this base with tannin and tartar emetic; the acid dyestuffs are mixed with soda solution and precipitated at the boil with the requisite amount of barium chloride, a solution of aluminium sulphate being then added until precipitation of the dyestuff is complete. The lakes must in every instance be washed quite free from soluble salts. In preparing rubber mixings with these lakes special care must be taken that all the materials used are absolutely dry, so that, as far as possible, the formation of hydrochloric acid within the rubber on cold vulcanisation may be prevented. The chances of damage to the shade of colour as the result of such formation of hydrochloric acid are certainly not very great, although this depends very much, of course, upon the nature of the particular coal-tar dye which was used in the preparation of the lake. But even the smallest production of hydrochloric acid is sufficient to entirely destroy the fastness of the colour towards water.

If it be desired to print in colour on the rubber surface, one may adopt the method given in Frankenburg and Weber's English patent, according to which the still tacky surface is dusted over with finely-powdered oxycellulose, the printing being done on this coating. Pigment colours (lakes) thickened with rubber solution are used, and most beautiful effects can thus be produced.

In selecting colour-lakes for rubber printing, the same points must be borne in mind as in selecting them for colouring the rubber mass, and reference may therefore be made to what has been said on that subject. But, in addition, it is of great importance that the covering-power of the colours used for rubber printing should be as great as possible. This condition is naturally best fulfilled by the mineral pigments, whereas all lake pigments have a tendency to transparency; this depends, however, upon their method of preparation, and especially upon the base used. If the printing is to be done on a white rubber surface instead of a coloured one, the case is, however, quite different, for then it is this transparency of the pigment which is its desirable quality, since it imparts to the print a brilliancy which cannot be attained by means of opaque colours.

In the waterproof industry some attention has also been given to the bronze-colour printing which has developed in recent years; indeed, more than in the calico-printing industry itself. The employment of this kind of printing is also conditional upon the use of cold vulcanisation in the case of all colours other than silver-white. Even the latter can only be cured by heat if it has been

printed with aluminium, and then the silvery lustre suffers considerably, doubtless on account of the presence of foreign metals even in the purest commercial aluminium.

In printing with bronzes, however, one important fact must be borne in mind; the ordinary coloured bronzes consist actually of alloys which always contain tin and frequently contain copper. The destructive action of copper on cold-cured rubber is well known, and the danger lying therein is augmented by the unavoidable action of the chloride of sulphur upon the copper during the process of vulcanisation. Non-recognition of this fact will result in considerable loss, for in the course of time the rubber in all the places covered by the copper-containing bronze becomes completely destroyed by oxidation, the waterproof material being perforated in these places right through to the fabric. Even tin alloys, which are frequently used, are not absolutely free from suspicion, for it is a well-known fact that tin bronzes, free from copper, give rise to an action quite similar to that occurring with copper. In every case examined the rubber coating proved to be comparatively highly vulcanised: in other words, too strong a solution of chloride of sulphur was employed; this appears to lead to the formation of haloids of tin, which have an oxidising action on the rubber. These difficulties can all be avoided by restricting oneself to the use of pure or tinted aluminium bronzes, which, in addition to their safety, are possessed of a much greater brilliancy than tin bronzes.

In conclusion, we may refer to the influences to which the starch is exposed if the chloride of sulphur is diluted. The starch adhering to the surface of the rubber is exposed in a high degree to the action of the vulcanising agent, and it is here that the property of retaining water, possessed by starch, comes in, a property which is a very undesirable one from the present point of view. Air-dried potato starch contains, on an average, as much as 20 per cent. of water, and it is evident that the presence of this must result in the decomposition of a considerable proportion of the sulphur chloride taken up by the rubber, a circumstance which is, in fact, responsible for the evil smell of the waterproof. This can be almost entirely avoided by using benzole as a solvent, and by employing only well-dried starch, still warm. The material must then be vulcanised immediately the starch is put on, and it is best to carry out the two operations consecutively on a combined machine. If, on the other hand, carbon bisulphide be used as solvent, the advantages gained by the use of well-dried starch, and of the combined powdering and vulcanising machine, are nullified by the deposition

of moisture on the surface, caused by the rapid evaporation of the solvent and the consequent great decomposition of chloride of sulphur which occurs on the moisture-laden starch. The hydrochloric acid set free in this decomposition often dextrinises the starch to such an extent that the material acquires an unpleasant black surface in place of the well-known velvety gloss.

The simplest method of getting rid of the unpleasant smell of cold-vulcanised materials is to let them run for a few hours through an airing apparatus in which air, heated to a temperature of about 70° C., is driven past them, removing the smell.

After-treatment of cold-cured waterproof with ammonia is of doubtful value, since certain impurities in the ammonia tend to make the smell worse. If it be possible, the cold-cured material

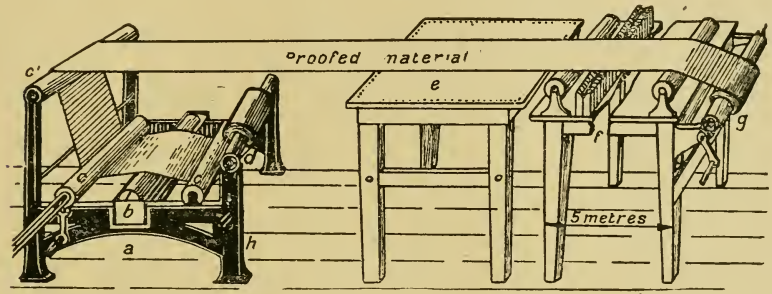


FIG. 42.

may be powdered with carbonate of magnesia, which absorbs the residual acid, and takes away the unpleasant odour.

The Cold-Vulcanising Shop.—This shop is situated in a separate building, primarily on account of the great risk of fire. The construction should be such that the building is provided with a double floor; the upper one, which is best formed of perforated iron-plates, stands about 1½ metres above the lower one, which is bricked or concreted, and on the ground-level. The space between the floors can be completely opened by means of valves, so that a current of air can pass through and carry away the vapours which descend through the upper perforated floor. The side-walls should have large windows all round, provided with glass jalousies, to ensure a vigorous circulation of air.

The most suitable machine for the cold-vulcanisation of waterproof cloth, reproduced in fig. 42, is very simple in its action. In the lead-covered frame *a* rests the solid wooden trough *b*, containing the beechwood roller, which revolves easily in two conical bearings.

Fig. 43 shows the wooden roller and trough in section. This wooden roller is one of the details in the process which is most worthy of attention; it must be turned so as to be absolutely true and perfectly smooth, and must under no circumstances become warped while in use; to this end special care must be exercised in the selection of a suitable piece of wood from which to make it. If the wooden roller gets warped, uneven vulcanisation will be the result, and spots and streaks will often be found on the finished article. The guide rollers over which the material is led are seen (*c c*) in fig. 44. The rollers *c'* are fitted into fixed bearings, while roller *c* runs in two movable levers, which make it possible to set the roller to any desired position, as shown in fig. 44. The object of this piece of apparatus is as follows:—A length of cloth is solutioned, on the spreading-machine, to each end of the material to be

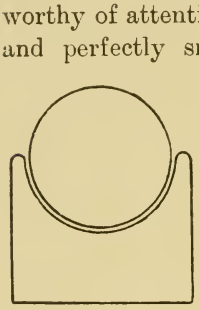


Fig. 43.

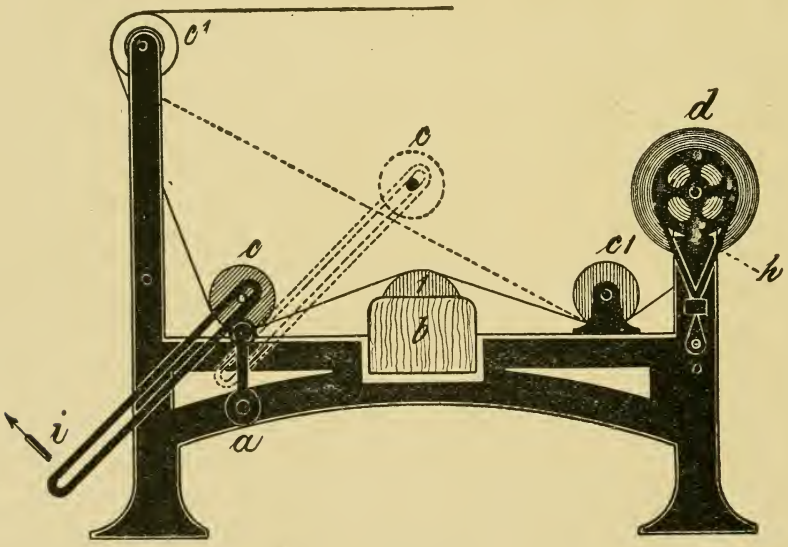


Fig. 44.

proofed. After proofing, the material passes, together with these end-cloths, on to the vulcanising machine, where it is rolled up as at *d*, figs. 42 and 44. The first end-cloth is passed under roller *c'*, over the vulcanising roller, then under *c* in slotted lever *i*, round *c'* over the heating-chest *e* and table *f* to roller *g*, on which it is rolled up until the join between the proofed and unproofed

cloths comes over the vulcanising roller 1. Lever *i* is then depressed by means of the handle *a* (fig. 44); this brings the proofed cloth on to the roller, and the vulcanisation can be started. When the other end of the proofed cloth, where it joins the other end-cloth, has passed the roller, lever *i* is raised. The final auxiliary cloth thus passes right above roller 1 and is not moistened by the vulcanising liquor, which would soon lead to its destruction. The roller *c* slides along lever *i* when the handle is raised or lowered, the lever being slotted. The two levers are connected by an iron bar, on which the handle is fitted. *e* is a heating-chest designed to hasten the evaporation of the solvent of the chloride of sulphur. *f* is an ordinary wooden table about 6 metres long, provided at each end with a guide roller, to prevent, as far as possible, rubbing of the material.

Just behind the front guide roller is an arrangement for discharging the electricity. This consists of two strips of wood (fig. 45), between which is clamped a copper-strip on to which a number of needles, with their points upwards, are soldered. The copper strip is connected, by means of insulated wire soldered to it, with a water tank outside. The needles are set with their points just below the level of the rounded edges of the wood, so as not to damage the cloth passing over them. At *g* (fig. 42) the proofed material is rolled up. The machine is belt-driven. An alternative construction of the machine is that in which a heating drum, 1 metre in diameter, is used instead of the heating chest. For the purpose of powdering the surface of the material, either before or after vulcanising, with potato-, rice- or maize-flour, a brushing apparatus is fixed behind the machine *a*, or else by itself; this is power-driven also, and by means of it the material is powdered with the flour and finely brushed. This method of powdering is employed in the case of the so-called electric-finished goods and single-proofed paletot-cloths.

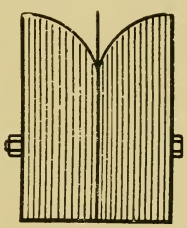


Fig. 45.

To return to the vulcanising process. Particular care must be taken to see that roller 1, in figs. 42 and 44, is clean. It should be rubbed dry with a cloth, because hydrochloric acid is formed upon it and must be immediately wiped off. When dry the roller is rubbed down with fine emery cloth, and then once again with a dry cloth. Before starting operations the trough *b* should also be carefully wiped out, the roller 1 being taken out for the purpose, and afterwards replaced so that it will revolve easily in its bearings.

At each end of the vulcanising roller a brass centre is let in, and into this the pointed brass screw projects. The screws are adjusted so that the roller runs easily: porcelain rollers and troughs have latterly come into use in place of wooden ones. When everything is in readiness the vulcanising liquor is poured into trough *b*, and vulcanisation now proceeds automatically in the manner depicted above. The material travels faster as it gets wound up on roller *g*, since the circumference of the roll is continually increasing; this is, however, an unimportant point; the rubber cannot be over-vulcanised by the quantity of solution taken up by the rapidly-revolving roller 1, for though on the one hand the roller takes up more solution the faster it revolves, yet, on the other hand, the time of contact between rubber and roller becomes continually shorter and shorter, and the net result is the same as at the original speed. The proofed material is uniformly vulcanised, and not, as is often thought, cured harder at the end. It may happen, however, that on account of the material running too slowly over the roller, the latter does not revolve fast enough to carry up the requisite amount of solution; the rubber is then under-cured, a result to be avoided. Should the roller not run with sufficient ease in its bearings, or should the centre of the roller not coincide with the centre of the wooden block out of which it was turned, the cloth will drag over the roll here and there, and in these places the rubber will be less highly vulcanised. One then wonders why the proofed material is good and bad in patches, the explanation being that given above. If the roller is turned from a cross-grained wooden block and has warped, the cloth will not make good contact with the hollows, and will take up too much liquor. The same thing will occur round the edges of the humps, too much solution being taken up where the material is not in close contact with the roller. These places become yellow, wrinkled, and hard. Now and again it happens that the vapours given off in the cold-vulcanisation process catch fire, owing to electric sparking between the cloth and some conductor or other. The material is electrified by friction, and if the potential difference is sufficiently great, the discharge takes place in the form of electric sparks. To prevent this firing, the apparatus already described is fitted up, a similar piece being placed behind the vulcanising trough. Should a fire occur in spite of these precautions, the cloth should be lifted away from the roller by raising the lever, and water should be slowly poured into the trough. The cloth is meanwhile rapidly run on, and not cut off. The flame burns low with a blue colour, and a pungent smell of sulphur dioxide

is given off. Material which is to be proofed on one side only is run over the vulcanising roller once; material proofed on both sides has to make two such journeys. Doubled stuff is generally vulcanised and doubled on the calenders (fig. 46). It is not necessary, however, to vulcanise both the cloths which are to be doubled together, as is often done. When two cloths are proofed for doubling, only one of them has a waterproof coat, this being the smoother of the two, while the other has only just sufficient rubber spread on it to make it adhere well. The first of these two cloths is vulcanised, the second not; for when they are carefully doubled

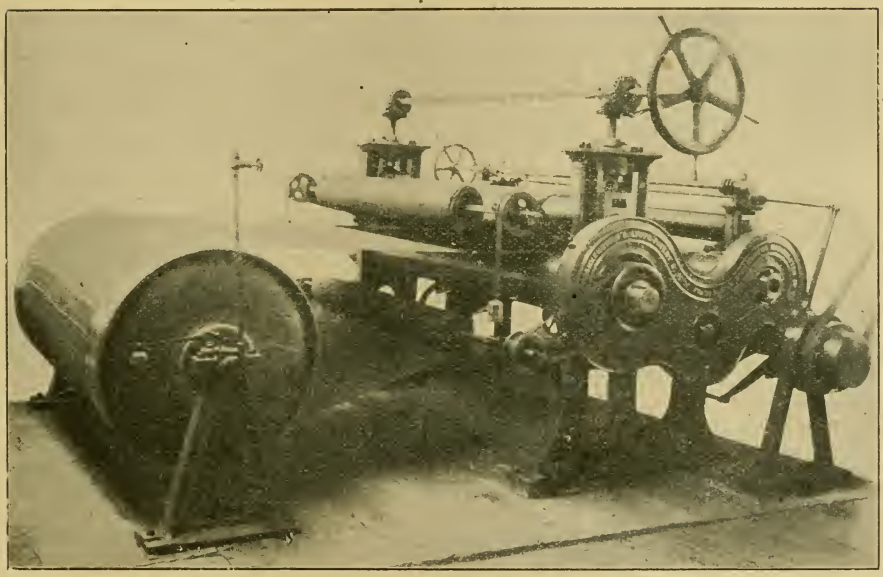


Fig. 46.

the lightly-proofed material is vulcanised when it comes in contact with that having the thicker coating of rubber. Fig. 47 shows diagramatically an arrangement for simultaneously vulcanising and doubling the proofed material. *a a* are the insulated cast-steel rolls, *b* is the vulcanising trough already described, *c c* the rollers upon which the cloth to be vulcanised and the lightly-proofed cloth respectively are rolled up, *d* also a wooden roller upon which the finished material is rolled up. After vulcanisation the material is hung up in a well-ventilated room to dry off.

The injuriousness of the vapours of chloride of sulphur and of carbon bisulphide is well known, and attempts have therefore been made to completely enclose the machines, and then to carry away

the vapours by means of fans. This arrangement is to be preferred. Fig. 48 shows how the enclosing of the vulcanising machine in the shop may be accomplished. The door and lid *b* are open for the

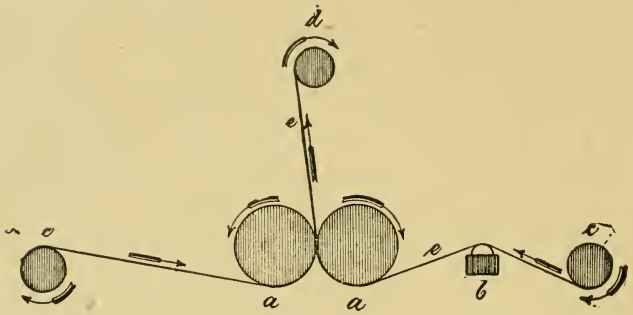


Fig. 47.

purpose of introducing the cloth; while the machine is in operation they are closed. *d* is a window to admit light into the chamber; through this the material can be watched, a condition which is absolutely necessary. *i* is the steam pipe leading to the heating

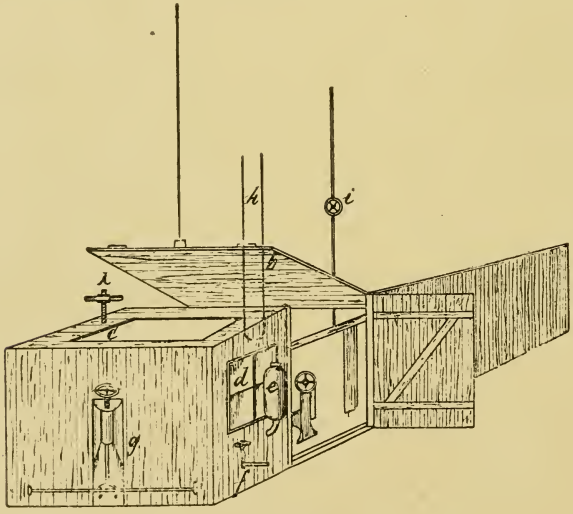


Fig. 48.

chest *e* of fig. 42. Before starting, the trough is filled as usual, and also the vessel *e* (fig. 49), the purpose of which is to replace the liquor in the trough automatically as it is used up. If the cloth gets creased, the lid *c* is opened, the hand is inserted through the opening, and the creases can then be easily smoothed out. The proofed cloth must obviously be braked in such a way as to cause

it to run under an even tension. In order to render this operation possible from outside the enclosure the brake *g* is provided. Vulcanisation with this arrangement is a pleasant process, in so far as that the poisonous vapours can scarcely be detected. The door and the lid *b* are closed while the work is going on. Air passes into the chamber through the opening *e*, and very little vapour can therefore escape. In fig. 49 the automatic arrangement for keeping up a constant level of liquor in the vulcanising trough is shown in diagram. *a* is an iron vessel, lead-lined, closed at *b* by means of an air-tight screw stopper. Tubes *e* and *c*, running side by side, lead from the vessel *a* into the vulcanising trough *f*, to a depth just below the level at which the liquor is to be kept. Tube *c* ends inside the vessel right at the top, whereas tube *e* only starts from the bottom. Vessel *a* is filled with vulcanising liquor through the opening *b*, which is closed again immediately after. On cock *d* being opened the solution now runs into the trough *f* until the level of the liquid rises just above the mouth of the tubes and closes them. When in the course of the vulcanising operation the level falls below the mouth of the tubes, more liquor flows from the vessel into the trough until the tubes are again closed by the rise in level, when the flow of liquor is checked; this goes on until, when work is finished, cock *d* is closed.

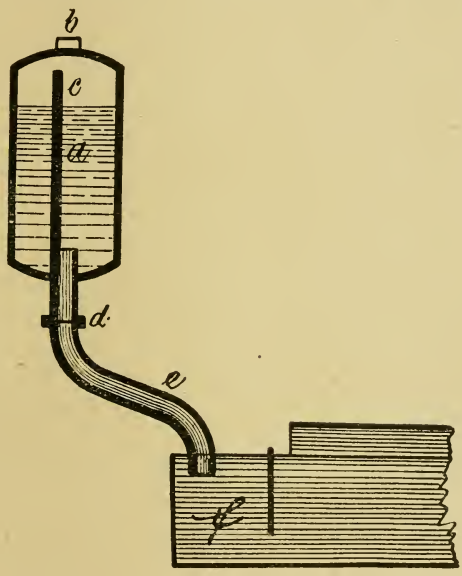


FIG. 49.

In addition to the room for vulcanising waterproof cloth, there are generally others for curing cut-sheet goods.

The ventilating pipe is usually fixed on the opposite side of the bench from that on which the workman stands; along the top of this runs a slot, through which the noxious vapours are drawn by means of a fan connected with the pipe. From the back wall of the vulcanising bench leading towards the rubber slot there rises a sloping hood which covers the whole of the bench with the

dipping vessels on it filled with carbon bisulphide; as an additional protection to the worker, a narrow ledge of wood runs along the front upper edge of the cover. The dipper stands in front of the bench and dips the small cut-sheet articles, by means of a fork held in his left hand, into a vessel containing the chloride of sulphur solution, whilst two others, sitting down, prepare the articles for dipping by mounting each one upon a separate prong of the fork. This arrangement for vulcanisation, although it is to be preferred to the older measures adopted for the protection of the workman, has nevertheless its own particular weak points. In the first place, the continuous exhaust slot leads to an imperfect removal of the vapours. Secondly, the sloping cover, and in particular the outwardly inclined ledge at the top, are in the way, and the workers get into the habit of stooping down below them, and so manage to inhale harmful quantities of the noxious vapours. Thirdly, the vessels containing the liquor are merely stood upon the bench, and the draught is only a very poor one, because of the great difference between the sectional area of the outlet and that of the opening in front (which extends from the top of the bench to the bottom of the protecting ledge on the sloping hood); the result is that the vapours are not entirely prevented from diffusing out into the room. The strength of draught necessary must be arrived at by experiment. Again, the arrangement is incomplete, since it affords no protection to the workers sitting in front of the bench preparing the articles for dipping, against the vapours arising from the dipping forks as they are handed back to them. All these imperfections can fortunately be remedied by adopting the following solution of the problem. The dipping bench is on that side of the room where the windows are, in such a position that the dippers stand on both sides of it opposite one another. The female hands, who fill the balloons, etc., have all their arrangements fitted up on the opposite side of the room, along the back wall. The ventilating apparatus consists of two entirely separate systems, viz. that for the general ventilation of the room, which may supply warm air, and that for local ventilation at the working places. The general ventilating system, the main trunk of which is made of galvanised iron, and suspended at a height of about 4 metres above the floor, carries fresh air, drawn in by a large fan, through the six nozzles to the upper parts of the workroom. This air, which is drawn by the second localised system of ventilation direct to the working places, sinks down past the workers without being contaminated to any appreciable extent by the vapours. The nose-pipes are 24 cm.

in diameter, and are arranged symmetrically in pairs; they pass the following quantities of air as determined by an anemometer:—

		Per minute.					
First pair	left-hand,	speed 300	metres,	quantity	13·5	cub.	metres;
	right-hand,	,, 284	,,	,,	12·8	,,	,,
Second pair	left-hand,	,, 280	,,	,,	12·6	,,	,,
	right-hand,	,, 320	,,	,,	14·5	,,	,,
Third pair	left-hand,	,, 280	,,	,,	12·6	,,	,,
	right-hand,	,, 240	,,	,,	10·5	,,	,,

in all, a quantity of 4590 cubic metres of air per hour. Further ventilation through the windows in the roof or top-lights is not advisable, as it would interfere with the general circulation of the system.

The draught on the working bench, which is quite independent of the general ventilation, is induced by a fan through a flue running along the floor the whole length of the shop. The fan drives the air charged with bisulphide vapours through an underground channel into the vertical air purifier outside the shop. The dipping bench is provided with two series of dipping vessels, placed alternately one on either side of the exhaust pipe, at intervals of about 1·5 metres. Each vessel is sunk into a pocket in the bench, its upper edge being flush with the bench top. The pocket is a fixture, with the exception that the front of it is made in the form of a flap, which can be opened. The small exhaust opening, through which the pocket is connected with the exhaust pipe, is situated underneath the dipping vessel, so that a protective draught of air is set up round the vessel by the suction, and a favourable means provided for the escape of the heavy vapours of carbon bisulphide and chloride of sulphur from the lowest point of the pocket. The top edge of the pocket is surrounded on three sides by projecting, slightly-inclined ledges, an arrangement which constitutes a distinct improvement, leading to efficient working. The remainder of the bench surface, which occupies the space between two pockets, is filled up with a hollow inverted pyramidal opening, covered with perforated metal, the apex of the pyramid leading into the exhaust pipe. By this means the vapour given off and the drops of liquor which always get splashed about during the dipping process, as well as the vapours coming from the forks after they have been in the liquor, are drawn away direct through the perforated plate to the exhaust pipe, and only traces of vapour are left behind, to be carried by the air circulation into the exhaust shaft.

CHAPTER III.

THE MIXINGS.

The mixings used in rubber manufacture are in part the results of rule-of-thumb experiments, and in part deductions from theoretical considerations. No generally acknowledged theoretical basis for mixing at present exists. The following are the principal points to be taken into account when devising mixings:—The use to which the article is to be put; the colour desired; the surface, whether it is to be quite smooth, or to have a cloth impression, or whether it is to be a matt or a highly polished surface; the limits of specific gravity, and of cost price. These points being fixed, one may proceed to base upon them a suitable mixing. The first question to decide is what kind of raw rubber will be most suitable. Outsiders often imagine that because Para rubber is the best it should be used by preference for all kinds of rubber goods, and that all other sorts of rubber are in a sense inferior for the purpose, or merely substitutes for Para. This view cannot, however, be altogether upheld. Para rubber is, in the first place, very high in price, and to employ it without just reason in a case where an equally good result could be obtained with a lower grade rubber is, from the standpoint of the rubber specialist, a crime, for the general adoption of this course of action would lead to an unnecessary diminution of the quantity of Para (which, as it is, is barely sufficient) available for purposes for which only Para, or practically nothing but Para, can be used; the demand for Para would consequently increase—that is to say, prices would go up still higher. For best quality air-tubes, elastic bands or rubber thread, practically nothing but best Para comes into the question; indeed, under some circumstances the original lots as delivered have to be sorted, and all the inferior pieces picked out and used for other purposes. For hard-rubber goods which are to be highly polished only such rubber can be employed as can be washed absolutely

clean, for the slightest amount of impurity remaining in the rubber would show itself in a very unpleasant way afterwards.

For "frictions" soft rubbers are the most generally used; for light-coloured, white and red goods, light-coloured rubbers are the most useful; for "floating" goods, naturally only such rubbers can be used as, when mixed with a sufficient quantity of sulphur and the necessary pigment, will still float. At this point we must correct a very widespread notion, which is none the less false, to the effect that every sort of raw rubber, if it be only correctly vulcanised, will float. One can very easily be convinced that most sorts of Aruwimi rubber, the lower grades being naturally the greater offenders in this respect, will not float even when vulcanised with only 10 per cent. of sulphur between the plates of a press. This phenomenon depends in part upon the contraction of the rubber during the process of vulcanisation, and cannot be predicted straight away. The favourite plan of attributing all faults to the wicked rubber resins is in this case also unjust, for as a rule I*a* Borneo, though showing, like Aruwimi, a high resin content, exhibits a medium power of floating after vulcanisation with 10 per cent. of sulphur; Guayule, too, when vulcanised under similar conditions, often floats, in spite of its high resin content. The contraction of rubber during vulcanisation depends to a very great extent, if not exclusively, upon the coefficient of vulcanisation. In some types of goods, which must possess considerable toughness, it is usual to work to a certain degree of contraction, by the addition of suitable ingredients, chiefly litharge, free from peroxide, in black goods, and, more frequently still, magnesia usta in red or light-coloured goods. Magnesia can, of course, be used in black goods, but not, conversely, litharge in red or light goods. Litharge is, in fact, always partially converted, during vulcanisation by heat, into the deep-black sulphide of lead. Now, since no sulphuretted hydrogen is given off during vulcanisation, as far as our knowledge at present extends, it may be that either the temperature employed is too high, or that by-reactions occur between sulphur and other substances present such as oils, certain resins, etc., sulphuretted hydrogen being evolved, or it may perhaps be assumed that on vulcanisation sulphur combines with rubber to form a sulphide-like compound, which then interacts directly with the litharge. The behaviour of mixings of this description when over-vulcanised also supports this view, for the coefficient of vulcanisation decreases as the amount of lead sulphide formed increases. This fact is at the bottom of the comparatively favour-

able effect on regeneration processes, of the presence in the waste rubber of large quantities of litharge.

There are a number of brands of litharge on the market which are more or less rich in peroxide of lead. Such litharge cannot be recommended for use with rubber, the peroxide having a tendency, under certain conditions which are not infrequent in practice (*cf.* heating tubes for railways, etc.), to burn the rubber. By certain authorities "dry heat" tests are prescribed, and in carrying out this test it is frequently observed that the test pieces from samples of rubber containing much litharge burn with a glow. It is not, however, necessary that the oxidation should be accompanied by visible combustion, for the so-called cold combustion is just as destructive to the rubber as the more apparent kind. The use of red-lead itself should, for these reasons, be entirely forbidden.

The use of litharge is limited by the facts, first of all, that it is only possible in dark goods; secondly, that it increases the specific gravity very considerably; and thirdly, that in many classes of goods it cannot be allowed, owing to its solubility in even dilute acetic acid, combined with the fact that it is injurious to health. It is true that in France and Switzerland wine-tubing is made from mixings containing litharge (or that such tubing is imported from Germany); still, it has not yet been shown that litharge is innocuous in that connection. Besides, there are no real grounds for the use of litharge for such a purpose, since the technical vulcanisation effect which is necessary can be produced equally well, if not better, by the appropriate use of magnesia usta.

Magnesia usta is commercially pure magnesium oxide, and is made by calcining magnesium carbonate. As a rule, however, about 2 to 3 per cent. of carbon dioxide remains obstinately fixed, so that the best magnesia usta of commerce contains only about 96 to 98 per cent. of magnesium oxide (MgO). Besides genuine magnesia usta there are on the market a number of products, also called magnesia usta, which contain considerably less magnesium oxide, together with a certain amount of carbonate or hydrate. The value of a particular sample of magnesia is therefore conveniently determined by re-calcining a weighed quantity and finding the loss in weight. In storing magnesia usta it must be remembered that this product tends to absorb carbon dioxide and moisture from the air, and the most convenient vessel to use for the purpose is a sheet-iron bin, with a closely-fitting lid, and provided with a slide so that the magnesia can be taken out without opening the lid.

The use of lime for the same purpose as magnesia usta has

fallen off, in spite of the enormous difference in price between the two products, in favour of a continually extending use of magnesia usta; from this it must be concluded that the results obtained with magnesia are much more satisfactory. Magnesia usta possesses over litharge the advantage of being innocuous—it is indeed administered internally as a medicine—in addition to the further advantages of not affecting the colour of the rubber, and of not increasing its specific gravity to so great an extent as litharge.

Litharge and magnesia usta are specially suitable for obtaining improved results from the vulcanisation of soft rubbers, which are generally rich in resins. From the same standpoint they are largely used in mixings which contain softening ingredients such as oils, paraffin wax, pitch, etc.

These additions of oils, paraffin wax, pitch, etc., are made principally with the object of helping to amalgamate such mixings as contain considerable amounts of ingredients like barytes, whiting, and especially carbon black, and which are, as a result, rather "dry," and of reducing their micro-porosity by removing from the mass the air which clings round the particles of the powdery ingredients. The solid fats, paraffin wax, ceresin and other waxes are liquefied before being added, and will then mix rapidly and easily with the rubber and other ingredients.

The principal colourings for which there is a demand in rubber goods are black, white, and red, and more seldom green. Other colours are only called for in exceptional cases. Blacks are produced by means of carbon black, lead sulphide, ferrous oxide, and pitch. Asphaltum has only a low covering power; there is practically no advantage in its use as against the use of pitch, and it is therefore hardly ever employed now as a colouring agent.

In addition to these pigments there is litharge itself, which blackens during the vulcanising process. The red pigments used are vermilion, Knapp's golden sulphide of antimony (antimony cinnabar), ordinary golden sulphide of antimony, and a number of mineral colours the basis of which is oxide or hydrated oxide of iron. For whites practically only oxide of zinc, sulphide of zinc, and barium sulphate are used to any important extent, the last two being generally used in conjunction in the form of lithopone. Antimony oxide is only very seldom used. For green one has to rely upon chrome greens, which are to be obtained in a variety of shades. For grass-green pure anhydrous chromic oxide is most suitable, while dark greens are best produced by chromium hydrate green or Guignet's green.

Substances used as fillers are whiting, barytes, and china-clay, in some special cases purified kieselguhr (atmido, atmoid, talite), for eraser-rubber anhydrous silicic acid and ground-glass, ground "galalith" (solidified milk albumen). The substitutes made from fatty oils—white substitutes by the action of chloride of sulphur, brown substitutes by the action of sulphur—which are addition products of these oils, must also be reckoned amongst the fillers.

Finally, the rubber manufacturer has still at his disposal for mixing purposes ground or prepared regenerated waste rubber. For special purposes various fibrous materials are of service, the chief amongst these being asbestos; ground cedar-wood waste from pencil-factories, hair, woollen-waste, graphite, etc., are also used.

In a very limited number of cases shellac and other resins are used. In a few instances talc is also added to mixings—for example, in rubber insulation for cables—but only good amorphous qualities are used for this purpose. Whiting is in many cases replaced by precipitated calcium carbonate, which, though more expensive, is finer, or by magnesium carbonate. A little wax may be added to hard-rubber mixings.

It is obvious that the substances to be added to a mixing must in all cases be selected with reference to the purpose for which the rubber is to be used.

Rubber articles which come into contact with food-stuffs should contain neither lead nor such zinc compounds as are soluble in dilute acetic acid; zinc oxide must therefore not be used in such instances. In this connection it should be mentioned that lithopone often contains considerable proportions of zinc compounds soluble in dilute acetic acid, as a result of the method of manufacture (Abschrecken), for only the zinc present as sulphide is insoluble in acetic acid. Lithopone should, therefore, always be examined by a competent analyst as to the amount of zinc soluble in acetic acid present. And in general a constant analytical control of all raw materials used in rubber manufacture cannot be too strongly recommended. The quantity of material used by a rubber factory in the course of a year amounts to such a goodly figure that it pays well to entrust the supervision of deliveries of material, and the accurate valuation of the supplies to be purchased, to a special member of the staff.

In rubber goods which are to be used in contact with acids, only those ingredients may be employed which are not attacked by acids, viz. barytes, atmoid (etc.), and pumice stone. Whiting must not be employed in tubing which is to be used for conveying wine,

beer, or acetic acid. In rubber which is to come into contact with caustic alkalies, the use of substitutes and of saponifiable oils should be avoided. Qualities to resist the action of oil are produced by the use of pitch in conjunction with litharge or magnesia usta. To minimise the action of bleach-liquor on rubber used in contact with it, additions of earth wax, ceresine, or paraffin wax may be made. Good electric insulation is obtained by the employment of mixings free from substitute and carbon black, and having a high coefficient of vulcanisation, which may be obtained by the use of magnesia usta. Further, in order to render such mixings as impervious as possible to moisture, additions of pitch, paraffin wax, ceresine, or ozokerite may be made. In this connection it should be noted that paraffin wax by itself is not absolutely devoid of the property of absorbing a certain amount of water, yet when it is mixed with rubber and sulphur and vulcanised, the product has an exceedingly low absorptive power. Goods which are to withstand high temperatures should contain no softening ingredients, and where, in addition, they come in contact with steam only limited quantities of substitute should be used.

The following series of *examples* of mixings illustrate the above remarks. No claim is made that these mixings are possessed of any general importance, as they can, of course, be modified in a great variety of ways:—

No. 1.—*Packing-sheet.*

Congo	1,500 gms.
Pontianac mixture	2,000 ,,
Reclaimed rubber	2,000 ,,
Waste rubber	10,000 ,,
Substitute	2,000 ,,
Barytes	10,000 ,,
Lithopone	15,000 ,,
Sulphur	300 ,,

No. 2.—*Packing-sheet.*

Guayule	4,000 ,,
Zinc oxide	8,000 ,,
Barytes	10,000 ,,
Sulphur	750 ,,
Magnesia usta	50 ,,
Canvas waste	7,500 ,,

No. 3.—*Packing-sheet.*

Congo	4,000 ,,
Reclaimed waste	4,000 ,,
Barytes	10,000 ,,
Lithopone	10,000 ,,
Sulphur	750 ,,
Magnesia usta	100 ,,
Waste with canvas	12,000 ,,
Euphorbia mixture	2,000 ,,

No. 4.—*Packing-sheet.*

Guayule	5,000 gms.
Whiting	5,000 ,,
Talite	2,000 ,,
Barytes	6,000 ,,
Litharge	1,000 ,,
Graphite	3,000 ,,
Sulphur	500 ,,
Magnesia usta	200 ,,
Hemp fibre	2,500 ,,

No. 5.—*Packing-sheet.*

Congo	5,000 ,,
Pontianac	3,000 ,,
Asbestos fibre	10,000 ,,
China clay	10,000 ,,
Talite	5,000 ,,
Barytes	10,000 ,,
Japan red (iron oxide)	5,000 ,,
Castor-oil	1,000 ,,
Sulphur	1,000 ,,

No. 6.—*Manhole-packing.*

Guayule	2,500 ,,
Pontianac mixture	5,000 ,,
Waste	25,000 ,,
Reclaimed waste	10,000 ,,
Barytes	15,000 ,,

No. 6.—*Manhole packing—cont.*

Lithopone	15,000	gms.
Canvas waste (proofed)	25,000	,,
Sulphur	1,000	,,
Magnesia usta	250	,,

No. 7.—*Water-hose.*

Congo	5,000	,,
Reclaimed waste	3,000	,,
Waste	15,000	,,
Pontianac mixture	2,000	,,
Substitute	8,000	,,
Lithopone	6,000	,,
Whiting	6,000	,,
Barytes	6,000	,,
Sulphur	1,500	,,
Magnesia usta	100	,,
Vaseline	500	,,

No. 8.—*Beer-hose.*

Mozambique	10,000	,,
Para waste	10,000	,,
Brown substitute	8,000	,,
China clay	5,000	,,
Lithopone[1]	5,000	,,
Barytes	5,000	,,
Vegetable black	1,500	,,
Pitch	500	,,
Sulphur	1,500	,,
Magnesia usta	200	,,

No. 9.—*Wine-tubing.*

Mozambique	10,000	,,
Reclaimed Para waste	5,000	,,
Lithopone[1]	5,000	,,
China clay	5,000	,,
Brown substitute	2,500	,,
Sulphur	1,500	,,
Magnesia usta	250	,,

No. 10.—*Acid-tubing.*

Para	5,000	,,
Cametas	5,000	,,
Sulphur	800	,,
Magnesia usta	100	,,
Ceresine	2,000	,,

No. 11.—*Acid-tubing.*

Para	2,500	,,
Cametas	7,500	,,
Sulphur	1,000	,,
Magnesia usta	50	,,
Talite	2,500	,,
Barytes	2,500	,,

No. 12.—*Oil-tubing.*

Guayaquil	10,000	,,
Reclaimed waste	5,000	,,
Litharge	2,500	,,

No. 12.—*Oil-tubing—cont.*

Talite	5,000	gms.
Pitch	500	,,
Sulphur	800	,,
Magnesia usta	250	,,

No. 13.—*Alkali-tubing.*

Mozambique	10,000	,,
Waste	5,000	,,
Pitch	500	,,
Talite	5,000	,,
Lithopone	10,000	,,
Sulphur	1,500	,,
Magnesia usta	200	,,

No. 14.—*Hose for latrines.*

Congo	10,000	,,
Reclaimed waste	7,000	,,
Lithopone	10,000	,,
Barytes	5,000	,,
Talite	15,000	,,
Sulphur	1,500	,,
Magnesia usta	250	,,
Vaseline	1,000	,,

No. 15.—*Heating-tube.*

Mozambique	5,000	,,
Reclaimed waste	10,000	,,
Barytes	5,000	,,
Lithopone	15,000	,,
Sulphur	400	,,
Magnesia usta	75	,,
Pitch	750	,,
Vaseline	1,000	,,

No. 16.—*Oil-valves.*

Cametas	5,000	,,
Guayaquil	5,000	,,
Reclaimed waste	6,000	,,
China clay	4,000	,,
Litharge	4,000	,,
Sulphur	1,000	,,
Magnesia usta	250	,,

No. 17.—*Para valves.*

Para	5,000	,,
Cametas	5,000	,,
Sulphur	800	,,
Magnesia usta	75	,,

No. 18.—*Acid valves.*

Cametas	10,000	,,
Ceresine	1,000	,,
Sulphur	1,500	,,
Magnesia usta	50	,,

[1] This lithopone should contain only traces of zinc compounds soluble in acetic, tartaric, or lactic acid.

No. 19.—*White (drab) valves for water.*

Mozambique	10,000	gms.
Zinc white	5,000	,,
Whiting	6,000	,,
China clay	6,000	,,
Light substitute	8,000	,,
Vaseline	1,000	,,
Sulphur	1,250	,,
Magnesia usta	200	,,

No. 20.—*Condenser valves.*

Mozambique	10,000	,,
Reclaimed waste	5,000	,,
Para waste	5,000	,,
Brown substitute	5,000	,,
China clay	5,000	,,
Lithopone	2,500	,,
Talite	2,500	,,
Litharge	2,500	,,
Pitch	250	,,
Sulphur	1,250	,,
Magnesia usta	250	,,

No. 21.—*Gas tubing.*

Cametas	1,000	,,
Ikelemba	4,000	,,
Para waste mixture	1,500	,,
Pontianac mixture	1,500	,,
Euphorbia mixture	1,000	,,
Zinc white	10,000	,,
China clay	7,500	,,
Lithopone	7,500	,,
Talite	5,000	,,
Reclaimed waste	5,000	,,
White substitute	5,000	,,
Brown substitute	5,000	,,
Castor-oil	1,000	,,
Vaseline	500	,,
Sulphur	1,000	,,
Magnesia usta	150	,,

No. 22.—*Gas tubing.*

Congo	8,000	,,
Euphorbia mixture	2,000	,,
Zinc white	15,000	,,
Whiting	10,000	,,
White substitute	10,000	,,
Vaseline	500	,,
Sulphur	1,500	,,
Magnesia usta	250	,,

No. 23.—*Gas tubing—red.*

Mozambique	10,000	,,
Brown substitute	5,000	,,
China clay	4,000	,,
Lithopone	6,000	,,
Iron oxide	6,000	,,
Golden sulphide	1,500	,,
Magnesia usta	300	,,
Ceresine	250	,,

No. 24.—*Gas tubing—black.*

Negroheads	8,000	gms.
Pontianac mixture	2,000	,,
Black substitute	5,000	,,
Barytes	5,000	,,
Talite	10,000	,,
Litharge	2,000	,,
Vegetable black	2,000	,,
Sulphur	1,000	,,
Magnesia usta	300	,,
Pitch	500	,,
Vaseline	1,500	,,

No. 25.—*Drainage tube.*

Mozambique	10,000	,,
Brown substitute	2,000	,,
China clay	5,000	,,
Lithopone	15,000	,,
Golden sulphide	2,500	,,
Magnesia usta	250	,,

No. 26.—*Mats.*

Niggers	5,000	,,
Pontianac mixture	2,000	,,
Reclaimed waste	15,000	,,
Waste (ordinary)	20,000	,,
Talite	15,000	,,
Vegetable black	1,000	,,
China clay	5,000	,,
Canvas waste	5,000	,,
Paraffin wax	2,000	,,
Sulphur	800	,,

No. 27.—*Bottle Washers.*

Para	4,000	,,
Columbian	6,000	,,
Black substitute	3,000	,,
Golden sulphide	1,000	,,
Magnesia usta	350	,,

No. 28.—*Bottle Washers.*

Cametas	10,000	,,
Black substitute	3,000	,,
China clay	2,000	,,
Golden sulphide	1,000	,,
Magnesia usta	300	,,

No. 29.—*Bottle rings (Codd's rings).*

Para	5,000	,,
Mozambique	5,000	,,
Brown substitute	3,000	,,
Talite	3,000	,,
China clay	1,000	,,
Magnesia usta	75	,,
Golden sulphide	1,500	,,
Paraffin wax	200	,,

No. 30.—*Buffers.*

Para	5,000	,,
China clay	5,000	,,
Soap-stone (Stearin-talkum)	1,000	,,
Litharge	1,000	,,
Pitch	250	,,
Sulphur	400	,,

No. 31.—*Buffers for insulation.*

Guayule	6,000	gms.
Pontianac mixture	5,000	,,
Reclaimed rubber	25,000	,,
China clay	30,000	,,
Litharge	5,000	,,
Vegetable black	500	,,
Sulphur	500	,,
Magnesia usta	250	,,
Pitch	1,000	,,
Vaseline	500	,,

No. 32.—*Rubber stoppers* (corks).

Negroheads	10,000	,,
Sulphur	800	,,
Magnesia usta	150	,,

No. 33.—*Rubber stoppers* (corks).

Negroheads	10,000	,,
Talite	3,000	,,
Sulphur	1,000	,,
Magnesia usta	100	,,
Ceresin	250	,,

No. 34.—*Rubber stoppers* (corks).

Para	10,000	,,
Ceresin	2,000	,,
Sulphur	1,000	,,
Magnesia usta	100	,,

No. 35.—*Cab tyre.*

Para	5,000	,,
Congo	8,000	,,
Zinc white	10,000	,,
China clay	10,000	,,
Talite	5,000	,,
Reclaimed rubber	5,000	,,
Litharge	2,500	,,
Pitch	500	,,
Sulphur	800	,,

No. 36.—*Washing-machine rollers.*

Mozambique	10,000	,,
Euphorbia mixture	1,000	,,
Lithopone	10,000	,,
Barytes	5,000	,,
Talite	5,000	,,
White substitute	5,000	,,
Paraffin wax	500	,,
Sulphur	1,000	,,
Magnesia usta	350	,,

No. 37.—*Diaphragms, for compressed air.*

Para	10,000	gms.
Pitch	100	,,
Sulphur	1,000	,,
Magnesia usta	150	,,

No. 38.—*Canvas hose.*

Mozambique	5,000	,,
Pontianac mixture	1,500	,,
Reclaimed rubber	5,000	,,
Talite	10,000	,,

No. 38.—*Canvas hose—cont.*

China clay	10,000	gms.
Litharge	1,500	,,
Sulphur	900	,,
Magnesia usta	200	,,

No. 39.—*Sponge rubber.*

Congo	5,000	,,
White substitute	2,500	,,
Talite	8,000	,,
Whiting	4,000	,,
Ammonium carbonate	1,500	,,
Oil of turpentine	600	,,
Sulphur	400	,,

No. 40.—*Hat-box.*

Para	5,000	,,
Cametas	5,000	,,
Brown substitute	2,000	,,
Sulphur	1,000	,,
Magnesia usta	75	,,
Pitch	100	,,

No. 41.—*Billiard-strip.*

Negroheads (pale)	5,000	,,
Substitute (floating)	1,000	,,
China clay	1,000	,,
Golden sulphide	500	,,
Magnesia usta	50	,,
Paraffin wax	100	,,

No. 42.—*Elastic bands.*

Para	4,000	,,
Congo	6,000	,,
Brown substitute (floating)	2,500	,,
China clay	2,000	,,
Golden sulphide	1,500	,,
Vermilion	200	,,
Magnesia usta	50	,,

No. 43.—*Balls.*

Congo	9,000	,,
Brown substitute	1,000	,,
China clay	5,000	,,
Zinc white	12,000	,,
Waste	5,000	,,
Paraffin wax	500	,,
Sulphur	1,000	,,
Magnesia usta	100	,,

No. 44.—*Frictions.*

Upper Congo or Ikelemba	8,000	,,
Reclaimed rubber	7,000	,,
Brown substitute	5,000	,,
Pontianac mixture	1,000	,,
Lithopone	15,000	,,
Whiting	2,000	,,
Canvas waste, proofed	5,000	,,
Sulphur	2,000	,,
Magnesia usta	500	,,

No. 45.—*Asbestos solution.*

Guayule	25,000 gms.
Dead Borneo	1,500 ,,
Substitute	750 ,,
Barytes	5,000 ,,
Zinc white	15,000 ,,
Sulphur	1,000 ,,

No. 46.—*Insulating tape.*

Guayule	5,000 ,,
Flakes	2,000 ,,
Barytes	20,000 ,,
Vegetable black	2,500 ,,
Lithopone	10,000 ,,
Tar, thickened	2,000 ,,
Castor-oil	1,000 ,,
Mica powder	1,000 ,,

No. 47.—*Cable rubber.*

Para	3,000 ,,
Congo	7,000 ,,
Litharge	1,000 ,,
China clay	10,000 ,,
French chalk	3,000 ,,
Pitch	700 ,,
Sulphur	500 ,,
Magnesia usta	300 ,,

No. 48.—*Para sheet for cables.*

Para I*a*, old	20,000 gms.
Sheet Balata	1,500 ,,
Sulphur	1,800 ,,

No. 49.—*Para sheet for cables.*

Para	20,000 ,,
Ozokerite	1,000 ,,
Paraffin wax	1,000 ,,
Sulphur	2,000 ,,

No. 50.—*Cable rubber* (for tube-machine).

Para	2,000 gms.
Congo	6,000 ,,
Balata	2,000 ,,
Pontianac mixture	2,000 ,,
French chalk	6,000 ,,
China clay	4,000 ,,
Zinc white	5,000 ,,
Litharge	2,000 ,,
Sulphur	700 ,,
Magnesia usta	175 ,,
Ceresin	2,000 ,,
Vaseline	3,000 ,,

No. 51.—*Thread.*

Para I*a*, old, sorted	10,000 ,,
Sulphur	750 ,,

Preparation of Golden Sulphide. — Bright red rubber goods, in the manufacture of which large quantities of golden sulphide of antimony are used, enjoy special favour, and on account of the importance of this pigment we may here be permitted to give an outline of its method of preparation.

Ordinary golden sulphide is obtained by decomposing sodium sulphantimoniate—Schlippe's salt—with an acid, for which purpose dilute sulphuric acid is generally employed. The Schlippe's salt is obtained by fusing together antimony ore (sulphide), dry sodium sulphate, charcoal and sulphur, extracting the melt with water, and concentrating the aqueous solution until the Schlippe's salt crystallises out. The crystals are centrifugalised in order to free them from mother-liquor, and then dried. An alternative method consists in boiling the black native sulphide with milk of lime, sodium carbonate, and sulphur, filtering and concentrating the filtrate to the point of crystallisation, the crystals being treated as above. The Schlippe's salt, obtained by either method, is then dissolved in water and the solution poured slowly into cold dilute sulphuric acid; the golden sulphide which separates out is allowed to settle in absence of air and light; the supernatant liquid is decanted, and the sulphide is then filtered off, washed free from acid, and dried in the dark, away from the air. In order to prevent the liberation of sulphuretted hydrogen, which is not only unpleasant but harmful,

the solution of Schlippe's salt may be precipitated by means of a solution of antimonious chloride, in which case a mixture of Sb_2S_5 and Sb_2S_3 in equimolecular proportions is obtained.

Knapp's golden sulphide, so-called, or antimony cinnabar, is obtained by the action of a solution of antimonious chloride on a solution of sodium thiosulphate, and forms a deep red powder.

Ordinary golden sulphide, the product first described, is antimonic sulphide (Sb_2S_5), and imparts a yellowish-red colour to mixings in which it is employed. The mixture of sulphides next described is antimony sulpho-sulphide, and gives a vermilion red colour. The last described, antimony vermilion, is antimony oxysulphide, and the colour produced by it is a cherry-red or wine-colour.

Ordinary golden sulphide dissolves readily in cold ammonium sulphide. Knapp's golden sulphide is only partially soluble in hot ammonium sulphide, but dissolves completely in sodium sulphide solution on prolonged heating. In addition to determining the actual shade and comparing it with standard, samples of golden sulphide should be tested to see that they are absolutely neutral, and the percentage of free sulphur should also be determined, by extracting the sample, in an apparatus similar to a Soxhlet's extraction apparatus, with carbon bisulphide which has been purified by distillation over oxide of lead.[1]

Manufacture of Substitutes. — In what follows we propose to give such details of the preparation of substitutes as will enable anyone to obtain a product quite free from any objectionable features. The data to be found in technical literature on the preparation of substitutes are in part very antiquated recipes of individual chemists, and in part excerpts from patent specifications, which are certainly possessed of little value. Even respectable journals are sometimes deceived, and we find them publishing, for example, recipes according to which substitute can be prepared by treating an oil with sulphuric acid. It is not often that one is able to trace the origin of the absurdity. In the instance just cited the worthy "professional scribe" has confused *Schwefelchlorür* (chloride of sulphur) with *Schwefelsäure* (sulphuric acid), in all probability because in the particular factory from which the recipe came chloride of sulphur happened to be called for the sake of brevity *Säure* (acid), a practice common to many factories.

It would be outstepping the purpose of this book to describe every process by which a useful "substitute" can be produced. It

[1] *Cf.* Esch and Balla, *Chemiker Zeitung*, 1904, xxviii. No. 50.

must suffice to deal with the most important kinds of substitute as examples.

We have, in the first place, to distinguish between the two classes of substitute, (*a*) the "chlorosulphide" substitute, which is white, and (*b*) the "sulphide" substitute, which is almost black in a compact mass, but varies in colour from yellow to brown when ground up. In each class of substitute a distinction is made between "fatty" and "dry," as well as betweeen "floating" and "non-floating" qualities.

White, floating, dry substitutes are prepared from rape oil—sometimes mixed with castor oil—and chloride of sulphur in such proportions as will completely "saturate" the oil. According to Henriques, pure rape oil requires for complete "saturation" the addition of 25 per cent. of its own weight of chloride of sulphur, whilst pure castor oil requires 20 per cent.; poppyseed oil, 35 per cent.; linseed oil, 30 per cent.; cottonseed oil, 45 per cent.; and olive oil, 25 per cent. The chloride of sulphur is, however, generally diluted with benzine before adding it to the oil, or else the oil or mixture of oils is itself dissolved in benzine. By this means a spongy mass of white substitute is obtained. The preparation is carried out in capacious hemispherical earthenware pans, and the mixture is vigorously stirred, both before and after the addition of the chloride of sulphur. If, for example, 15 kilos. of castor oil and 10 kilos. of rape oil are to be used, the amount of chloride of sulphur required will be 5·5 kilos., and to this 1 kilo. of light benzine can be added with advantage. If a slightly less dry substitute be required the proportion of chloride of sulphur must be diminished. The substitute so obtained is ground up and placed on racks in a room in which it is allowed to dry off, the air in the room being rapidly renewed. Very often shallow trays containing quicklime are placed in these racks between the shelves on which the substitute lies, so that the acid vapours given off are absorbed by the lime. In other cases magnesia is dusted over the substitute with the same end in view, and also with the further object of counteracting the softening effect of large additions of white substitute to a mixing. Substitute treated in this way can, however, only be used in hot-cured goods. There are makes of substitute on the market which contain as much as 5 per cent. of magnesia, and although these are certainly specifically heavier than other sorts, the results obtained with them on vulcanisation are far superior. It is also customary in some instances to wash white substitutes, but the practice is not very frequently adopted.

Fatty white substitutes are prepared, as already stated, by using a lower proportion of chloride of sulphur, and sometimes by modifying the proportion of rape to castor oil at the same time. Hence there are numerous possibilities of variations in the process. One such variation may be instanced, viz. 25 kilos. of rape oil, 4·3 kilos. of chloride of sulphur, and 1 kilo. of light benzine.

It may be added that satisfactory results can also be obtained by the use of other oils, but it is impossible to go into details. Many manufacturers work out, for their own special use, a substitute which would be ill-suited for sale in the open market, but which is cheap and suits their own purposes, and can therefore be used in their own manufactures without any hesitation.

In brown substitutes, also frequently known as "black," a distinction is made between substitutes made from the raw oil and those made from blown oils. Amongst the latter the so-called "Para-factis," which contain mineral oils, vaseline or paraffin wax, are deserving of special mention.

The following recipe may be quoted as an example of the preparation of a very useful brown substitute:—100 kilos. of raw rape oil are heated at about 160° C. with 16 to 18 kilos. of sulphur in a suitable vessel provided with tipping gear. Heat may be applied either by means of a gas-ring burner or by steam; in the latter case a jacketed vessel must be used. The liquid mass is carefully stirred whilst being heated until just before the conclusion of the process, a point which is to be recognised by the liquid frothing and seething up in the vessel. The stirring is done with a paddle (generally a wooden one), and its main object is to prevent the fused sulphur from collecting on the bottom of the vessel. There is no object in using finely ground sulphur, because the sulphur first melts and sinks to the bottom of the vessel, and it therefore makes no difference whether flowers of sulphur or block sulphur is employed. Much higher proportions of sulphur than those given above may be used, but it should be borne in mind that goods manufactured from such substitutes behave differently on vulcanisation from those containing substitutes with lower proportions of sulphur. On account of the frothing which occurs, a very capacious vessel should be used. It is advisable, after the last vigorous reaction is at an end, to pour out the contents of the heating vessel into large shallow pans, where it sets to a dark mass; this when quite cool is finely ground. A substitute prepared in this manner is exceedingly elastic, and mixes well with rubber. When heated to a temperature of 145° to 155° C., and subjected to

slight pressure, it again becomes viscous, and therefore distributes itself very evenly throughout the mass of rubber, in the case of goods vulcanised under high steam pressure, even if the mixing has been imperfect. By slight modifications of this process, having as their object the combination of larger proportions of sulphur with the oil, substitutes of a stiffer consistency, which are, however, at the same time harder and not so easily liquefied during vulcanisation, can be obtained; hence many processes similar to the above are in simultaneous use, in order to meet the needs of different consumers.

The brown substitutes prepared as described above are always non-floating. It is often desirable, however, to use substitutes which are specifically very light, and to meet this requirement the oils are oxidised before being submitted to a gentle sulphuration. The oils are heated for several days, a current of air being meanwhile passed through them, and they are then treated with sulphur. As a rule, however, the substitutes obtained in this way do not quite float, although some firms have succeeded in producing some fine floating substitutes solely by this method, without any addition of mineral oil or paraffin wax. The non-floating substitutes from oxidised oils are generally prepared in the rubber factory itself, whilst the really floating kinds, the so-called "Para-factis," are often referred to special substitute factories. A variety of products can be obtained, according to the duration of the oxidising process, and the amount of sulphur added. Generally speaking, it may be said that a substitute made from an oil that has been very fully oxidised, and to which a correspondingly smaller proportion of sulphur has been added, is specifically lighter, but has at the same time a considerably higher melting-point than one which has not been oxidised for so long a time. Some manufacturers, at least, prefer to use for inner tubes and similar qualities substitutes of low melting-point rather than those which melt at a higher temperature. The best plan would appear to be, therefore, to ascertain by experiment the kind of substitute most suitable for each particular purpose, and not to treat all brown substitutes alike.

It it be desired to prepare the so-called Para-factis in the factory, oxidised castor oil must be used instead of oxidised rape (according to Höhn), and to this one-third of its own weight of vaseline, or of a mixture of mineral oil and paraffin wax, must be added. The sulphuration is then carried out in the manner described.

Special kinds of substitute, to which asphaltum or ordinary

pitch has been added, are used, less in rubber goods than in insulating masses for electric cables. The use of such substitutes is restricted to dark-coloured mixings.

Mention must be made of certain kinds of coloured substitutes, prepared by colouring the oil mixture before treating it with chloride of sulphur. The use of these coloured substitutes is limited to cold-cured goods, since they are destroyed by hot vulcanisation. As is well known, all chlorosulphide substitutes are converted at the higher vulcanising temperatures into dark viscous oils which, unlike those into which the brown sulphide substitutes are converted by heat, do not set again on cooling. All chlorosulphide substitutes do not decompose with equal facility. If in the manufacture of light-coloured goods it is desired to use white substitute, it is advisable to use as low a temperature as possible for vulcanisation, this being rendered possible by the use of suitable quantities of magnesia.

The colours used for colouring chlorosulphide substitutes must be stable towards acids, and non-poisonous.

Many rubber factories are obliged by local conditions to get their substitutes from special substitute factories. Such bought substitute is generally examined as follows:—White substitute is warmed with distilled water, to which is added a drop or two of a solution of phenolphthalein, rendered faintly pink by addition of a trace of alkali. If the pink colour remains—care being taken to exclude air—the substitute is practically free from acid. If the pink colour deepens, as often happens, it means that the manufacturer has added an excess of magnesia or other neutralising agent, and so has made the substitute alkaline. Nothing is to be said against this. The second test consists in comparing the carbon bisulphide extract of the substitute with that of an approved standard sample. Substitutes which are strongly alkaline should be extracted with benzol in preference to carbon bisulphide, since the latter is decomposed by alkalies, but in that case the comparison should be made with the benzol extract of the standard sample. The amount of ash or of magnesia present in a sample of substitute is also occasionally of interest to the manufacturer. Substitutes to be used for cold-cured goods must be perfectly neutral, and must therefore not contain magnesia. Substitutes which do contain magnesia are generally heavier than water, but for the same reason they are rather more stable towards heat, as may be determined by heating in a drying-oven at 150° C. In cases where the chloride of sulphur, used in the manufacture of white substitute,

contained an excess of sulphur, a corresponding quantity of free sulphur is found in the benzol extract. This, however, occurs very rarely.

It scarcely ever happens that brown substitutes contain free acid, since only crude oils are used—oils, that is, which have not been refined by means of sulphuric acid—and since in the process of manufacture only neutral sulphur is employed. But individual samples of commercial products should be very carefully examined as to the percentage of constituents present which are soluble in hot acetone. This extraction is carried out in a Soxhlet or similar apparatus. The acetone extract is evaporated to dryness and the residue weighed. The residue is then extracted several times with a measured quantity of cold acetone, and the second residue dried and weighed. The difference between the weights of the first and second residues represents approximately the amount of unchanged (non-sulphurised) oil present. The second residue may consist of free sulphur and of paraffin wax, mineral oils, etc. It is treated with strong alcoholic potash until all the sulphur is dissolved, the alcohol is got rid of by evaporation, the residue thoroughly washed with hot water, and any residue of paraffin wax, etc., is weighed. It is true that only approximate numbers are obtained by this method, since it is only a rough one, but still the numbers obtained will give a sufficient indication of the nature of the substitute to an expert. A suitable quality having been selected from amongst the various commercial sorts, the application of this method of examination, combined with determinations of melting-point and specific gravity, will afford the necessary means of deciding whether a new sample of substitute is equal to that which has been in use hitherto. A brown substitute which is to be used in the manufacture of red-rubber goods should be examined as to its colour-absorbing power, and the colour of the ground product should be carefully taken into consideration. The best way of carrying out these tests is by preparing and vulcanising test-mixings.

The Treatment of Besk for use in Rubber Mixings.—The well-known unpleasant-smelling pseudo-rubber called Besk, Pontianac, dead Borneo, Gutta-Jelutong (which is now almost indispensable), always contains a great deal of sand and fragments of wood, even after it has been carefully cleaned on the washing-rolls, so much so that it is not often, or only in the lowest grade mixings, that the washed product can be used without further purification. Besk contains a small proportion of a useful rubber hydrocarbon, the isolation of which may possibly come to be regarded in the

future as a paying process, but the presence of an enormous proportion of resins, together with the difficulty of removing mechanical impurities, greatly detracts from its value. There are a number of ways in which Besk can be prepared for use in rubber mixings. One of the simplest consists in dissolving the Besk in, or melting it down with, 25 to 40 per cent. of its weight of castor oil, and filtering the thick solution so obtained through sieves which can be heated. About 5 to 10 per cent. of magnesia usta is then added to the filtered mass in order to bring about good results on vulcanisation. Tar, freed from naphthalene by evaporation, is also used instead of castor-oil in other instances; in that case, however, the Besk mixture can only be used for dark goods. A more usual method of purification than that which involves the solution, melting, and filtration of the Besk, consists in forcing it through very fine sieves by means of the tube machine. Besk mixtures are generally used in order to remove the "dryness" from such mixings as contain large proportions of ingredients like barytes or whiting, and to make them easier to work up for a variety of purposes. Quite colossal quantities of Besk are also used for proofing asbestos and other fabrics in the manufacture of packings. In these cases it is merely good sticking properties that are necessary, elasticity being of quite minor importance.

Asphaltum and Pitch as Ingredients of Mixings. — Asphaltum and pitch are often added to dark mixings in order to produce "density," and to render the goods less susceptible to oxidation. These additions also facilitate the mixing of powdery ingredients, and there is less risk of the rubber getting "killed" upon the mixing-rolls. Moreover, the addition of pitch either brings about only a very slight increase in the specific gravity of the mixing, or it may even help to lower it. Natural asphaltum is not always pure enough to add directly to the mixing without further trouble. If it is very rich in mineral and, as in some instances, woody constituents, it is advisable to dissolve it in a suitable solvent, filter the solution, and then drive off the solvent again. The usual forms of extraction apparatus are most suitable for this purpose, the more modern forms being so perfect in design and construction that only a very small percentage of solvent is lost in the whole operation. Generally speaking, the use of asphaltum has fallen off very much for some considerable time, for the same effects can be produced by means of pitch, which is cheaper. In the preparation of this pitch, various kinds of tar, chiefly coal-tar, are thickened by evaporation until all traces of naphthalene are removed, and the tar is converted

into an extremely viscous, almost solid, pitch. Either hard, pure asphalt or Carnauba wax is sometimes added to the pitch in order to raise its softening point. Some makes of pitch are often met with in commerce which are thickened by the addition of resin; such pitches are not to be recommended.

The addition of pitch considerably increases the gas-tightness of rubber, and also diminishes its water-absorption; the latter property is of especial importance in cable mixings.

Fats, Oils, Paraffin and other Waxes in Rubber Mixings.—At first sight it seems absurd that, in spite of the well-known destructive action of fats and oils upon vulcanised rubber, not inconsiderable quantities of such substances should often be added to the mixings. But when it is realised that the destructive action of oils must proceed from the surface inwards in order to bring about complete destruction of the rubber mass, and that the extent of the destructive action depends very much upon the amount of oil present on the surface of the rubber, it will be seen that the oils which are added to a mixing, in quantity which is never so great as to cause the rubber mass to swell up to the extent necessary to bring about its destruction, cannot in the ordinary way cause any appreciable damage to the rubber goods in which they are used, provided they are used with discretion. Moreover, the use of oils is limited, on the whole, to those mixings which either contain a great deal of waste rubber, or a large proportion of ingredients tending to make the rubber porous. Leaving hard rubber out of account, the materials mentioned in the heading to this section are either not used at all in the finer mixings, or only in the smallest quantities.

Naturally it makes all the difference in the world whether the oils, etc., are added to the mixing before vulcanisation, or whether they act locally on the surface of the rubber mass after vulcanisation. A whole series of oils, etc., are partially sulphurised when suitably vulcanised, although it is only in the case of hard-rubber goods that the combination of oil with sulphur goes on to such an extent that one can talk about the formation of compounds similar to substitutes. Exaggerated notions as to the formation of substitute from castor oil, rape oil, etc., during vulcanisation sometimes exist amongst rubber workers; for it is very easy, by putting through an acetone extraction of such rubber mixings, to show that practically all the oil added remains, after vulcanisation, soluble in acetone; that is to say, that only a minimum quantity (or none at all) of substitute insoluble in acetone has been formed, unless, of

course, very high temperatures, or ingredients which act quasi-catalytically, have been employed.

In the use of saponifiable oils in conjunction with saponifying agents such as lime, magnesia, litharge, zinc oxide, etc., the purpose which the goods are destined to serve must have a decisive importance attached to it. Such additions in notable quantity should be used in steam packings only with great caution. The use of saponifiable oils, of linseed oil in particular, in soft-rubber goods should be as far as possible avoided. Rosin oil is often deceptive in its action, a strikingly good effect being first of all produced, very soon followed, in the case of goods in the manufacture of which appreciable quantities of the oil have been used, by a ruinous hardening. Rosin oil, as is well known, is very susceptible to chemical change, and should therefore only be used in small quantities in practice. Opinions with regard to palm oil differ very widely. Whereas by some it is regarded as a very valuable addition, others consider it more dangerous than linseed oil. There is much to be said for both opinions, for very much depends upon the quantity used, and upon the many special points about the mixings in which it is employed.

The pale, heavy mineral oils, as well as vaseline and paraffin wax from petroleum, are especially largely used. These bodies are practically unaffected by the process of vulcanisation, and, provided their bromide absorption coefficient is low, they are also practically unaffected by other chemical influences, including that of the atmosphere. These statements do not apply with absolute exactitude to shale oil, or to analogous products of peat distillation. The products from these two sources corresponding to the petroleum products referred to above have generally an unpleasant smell similar to that of solar oil, which serves to indicate their presence. Some of them have an enormously high bromine absorption, which points to the presence of unsaturated hydrocarbons of the olefine series, and are therefore able to combine with sulphur when heated with it, liberating considerable quantities of sulphuretted hydrogen in the process. This reaction of the peat distillates finds application in the preparation of ichthyol products; they are of very little use for rubber goods. Ceresine, obtained from ozokerite or earth-wax, is used with advantage in rubber manufacture; unfortunately pure ceresines are rather expensive, and the wax is often adulterated. There is nothing to be said against the use of the cheaper ceresines, which are adulterated with good paraffin wax, provided they are sold as such mixtures. But besides these true "mixed" qualities

of ceresine, there are many kinds on the market which are adulterated with rosin and other cheap filling and colouring matters; against these it is only necessary to utter a note of warning.

It is only in the manufacture of the various qualities of hard rubber that the use of waxes is of any very great importance, and the different kinds of wax are often used in conjunction with one another. The most frequently used are Carnauba wax and Chinese wax, although Japan wax, which belongs to another class, has recently come into fairly extensive use.

In some factories stearic acid is used instead of paraffin wax. In this connection the possibility of the goods in which it is present coming in contact with metals must be taken into account, since stearic acid, as is well known, acts vigorously upon a whole series of metals.

There is one novelty which is worthy of note here: that is, the highly-oxidised castor-oil manufactured by a South German firm; with the aid of this it is possible in some cases to dispense with the use of the more expensive Besk mixtures and similar very adhesive ingredients. Sometimes the oil in question is heated with sulphur before being mixed with the rubber, but not to such an extent as to lead to the formation of substitutes.

The foregoing account cannot, of course, lay any claim to completeness, although the most important oily and waxy ingredients have been referred to. The authors are unfortunately not in a position to report upon the results of experiments with oils polymerised according to Axlerod's patent, which were stated on his part to be suitable for use in rubber mixings. In this process of polymerisation, as is well known, aluminium chloride is employed as the catalytic agent for effecting polymerisation. It may also be mentioned that Tung oil, polymerised by heat, has been recommended as a kind of substitute with the properties of a wax, but this product will not easily find general use, on account of its unpleasant smell.

CHAPTER IV.

THE MANUFACTURE OF SOFT-RUBBER ARTICLES.

1. Manufacture of Hose.—(*a*) Vacuum and Pressure Hose, with and without Insertion, for Conveying Purposes.—In the following pages our intention is to describe the manufacture of hose as carried out to-day in modern works. As may be gathered from the plan of the factory, the hose department is located in the largest shop, the whole breadth of which is available for use, no obstructing columns or pillars being present. This is a great advantage, because the metal mandrels, 40 metres long, on which all large-size hose and all tubing with insertion has to be made up, can then be carried without hindrance from the working bench to the wrapping machine, and from there to the trolleys on which it is run into the vulcanising pipes.

The method of manufacture formerly adopted, and which is still employed in many works, was to lay the calendered sheet of rubber round the metal mandrel, which had previously been rubbed over with French chalk, press the overlapping edges closely together, and then cut along the tube from end to end. The cut edges were moistened with benzine, and were then pressed together and kept in position by a strip of rubber which was laid on top. This is the method of manufacture still employed in the case of hose of large dimensions and of qualities which do not lend themselves to being dealt with on the machine. In the case of good qualities, where the cut edges adhere together well, this method is also less risky; on the other hand, in the case of qualities in which the cut edges do not adhere well together it is better to use the tube machine method, which was first introduced in America, but which has since been adopted almost universally.

The manufacture of hose is generally carried out in the following three stages:—

1. Running the inside and outside coatings on the tube machine.

2. Wrapping on the insertion.
3. Wrapping the hose prior to vulcanisation.

There still exist many factories in which the machining of the inside coat of rubber is still done on the ordinary tube machines, and the sleeve obtained then drawn on to the mandrel. But this method has the following disadvantages: in the first place the rubber gets contaminated with French chalk; and secondly, thin places are formed, owing to the uneven stretching which it receives during the process of pulling it on to the mandrel; small particles of compounds, also, the presence of which is due to careless mixing, form weak spots through which the liquid can find its way into the insertion, perforating this and making the hose unfit for use. The contamination with French chalk causes a bad join to be made, unless the chalk is washed off quite clean with benzine. But if the manufacture is to be carried out on thoroughly business-like principles, tube machines must be used through which the mandrel can be driven and the rubber squeezed out round it. Besides the reduction in the amount of labour required to make hose by this method, one has, in addition, the advantage of obtaining a uniform thickness of wall, even in the case of the very thinnest-walled tubing.

The construction of this machine has been so greatly improved that it now forms a perfect type, as illustrated in fig. 50. The mandrels are introduced through the hollow screw, and with their coating of rubber are carried forward, more or less rapidly, immediately on leaving the machine, by an endless conveyor with grooves on its working surface to take the mandrels. The speed of the conveyor is regulated by means of a friction driving-pulley fitted on to the machine. In order to prevent the rubber from sticking to the mandrel, the latter is finely powdered with French chalk after entering the hollow screw, by means of a blowing apparatus attached to the machine, and supplied with air from a small fan. Instead of the usual feeding-hopper, this machine has a pair of feeding-rolls, which force the rubber into the screw at a uniform rate, and uniformly heated. Should the screw receive a little too much rubber at any time, the rolls are raised by springs and do not carry any more forward until the screw has worked off the excess. By this arrangement the troublesome choking-up of the machine is done away with and inequalities in the thickness of the rubber tube are avoided. As the mandrel leaves the nozzle of the machine it passes on to the conveyor in front of it, by which it is carried along at a speed corresponding to that of the machine.

As soon as the whole length of mandrel is covered with rubber it is laid on a bench near at hand, and in the case of hose with insertion the second stage of manufacture is begun, namely, the wrapping round it of the insertion.

The best way of doing this is still by hand, for all the insertion wrapping-machines hitherto constructed have the disadvantage that the layers of cloth must not overlap, for if they do the pressure of

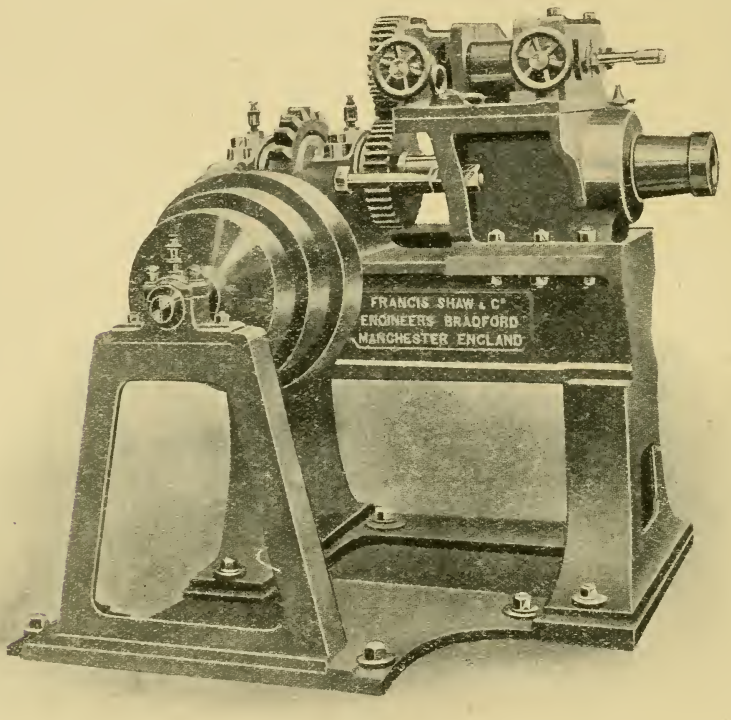


Fig. 50.

the top roller will tend to cause the inside coating to be penetrated by the cloth where the extra thickness, due to the overlap, occurs. On the other hand, attempts to butt the edges of the canvas are attended by the danger of leaving the hose liable to be easily burst. The safest plan is, therefore, in the case of hose with hemp or cotton insertion, to proceed as follows:—The proofed canvas is cut on the bias into strips of such a width that they will go round the hose the required number of times; these strips are united by overlapping their ends to the extent of about 12–15 mm. and firmly

rolling them together, and the long strip thus produced is now laid over the rubber sleeve (on the mandrel) and gradually rolled on to it, by means of small hand-rollers, round the whole circumference, until the beginning and end of the canvas are in superposition, after the required number of turns have been made round the circumference. When this part of the process is completed the hose is tightly stretched on the mandrel and bound on to it at both ends. The whole then passes through the hose machine again, when the outer coat or cover is put on; during this process, however, the chalking apparatus is not brought into action. As soon as the outside coat has been put on, the hose is ready to be wrapped, a necessary preliminary to vulcanisation.

Before going into the details of the third stage in the manufacture of hose, it will be as well to get a clear idea of the object of the wrapping process; this is essentially as follows:—As made upon the mandrel the hose is not yet sufficiently compactly bound together as a whole, and it may therefore easily happen that places are left between the insertion and the rubber coating where these two do not adhere together well. For this reason, this kind of hose is wrapped, before being vulcanised, with one or more strips of cotton, wide or narrow according to circumstances. The whole length of rubber being now tightly bandaged, it is shaped, during vulcanisation, into a perfectly cylindrical tube. The cloth impression visible on the surface is produced of course by the wrapping-cloths, which are removed after the hose has been cured. If the wrapping is badly and unevenly done, or if the tube is not drawn on tightly enough, air blisters may be formed during vulcanisation, which may rupture the cloth and make the hose unsaleable, if the damage cannot be repaired by cutting a piece out, making the place good, and curing once more. In insertions spread with solution the presence of moisture is a factor which may give rise to porosity or blistering, and bad mixings may also cause the whole of the inside and outside coats to blow and become porous. As a rule the wrapping is done, in the case of a hose 40 metres long, by a gang of fifteen to eighteen hands, twelve to fourteen of whom give to the hose, which is lying on a bench, a forward rolling motion, while a man at the upper end pulls at the mandrel; three more hands are necessary to hold the wrapping-cloth and roll it on. With the mechanical wrapping-machine (fig. 51) the method of procedure is much simpler. The hose is supported on the two lower rolls. A strip of cloth of the right width having been wrapped round the end of the hose at a sharp angle, the upper pressure-

roller, which is of just the same length as the under rollers (the actual length of roller for a 40-metre length of hose being 42 metres), is lowered, and the machine set in motion. The wrapping process is now accomplished automatically, the hose rotating about its own axis on the two rollers, while the upper roller presses the cloth tightly on to the hose; meanwhile the man in charge of the wrapping-cloth has only to see that it is kept tightly stretched.

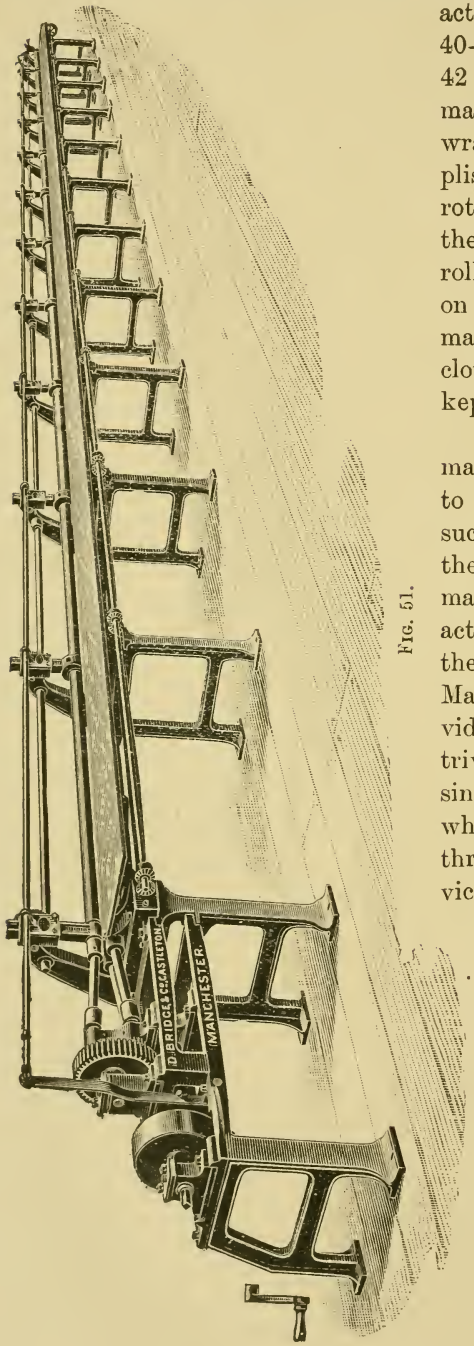


Fig. 51.

In purchasing a wrapping-machine it is of importance to select one constructed on such a system as permits of the upper roller being automatically lifted, by eccentric action, whenever the wall of the hose runs a little stouter. Machines which are not provided with some such contrivance are of doubtful value, since the variable pressure which they exert tends to rub through the hose. A very serviceable and entirely new kind of wrapping-machine is illustrated in fig. 52; this machine has met with great approval during the short time it has been working, and it embodies the simplest of principles. The hose is driven by means of a chain and chain wheel in connection with a variable-speed friction drive. The elements of the latter can be adjusted to run alter-

nately in either direction, and the output of the machine is exceeded by no other make. In the case of hose up to 19 mm. in diameter, made from suitable mixings, a single binder is sufficient, but when this diameter is exceeded the hose is wrapped twice, up to a diameter of 28 mm. Hose of greater dimensions still must be wrapped three and often four times. If, however, it is found necessary, in any given instance, to wrap a hose of normal dimensions (say about 40 mm.) six or eight times in order to produce a perfect article, it is pretty certain that there is some great mistake in the composition of the rubber. At the same time, it may be mentioned that hose with cloth insertion is also made with a smooth surface, with false seam-markings running the length of the hose, so-called "hose made by the English method." This

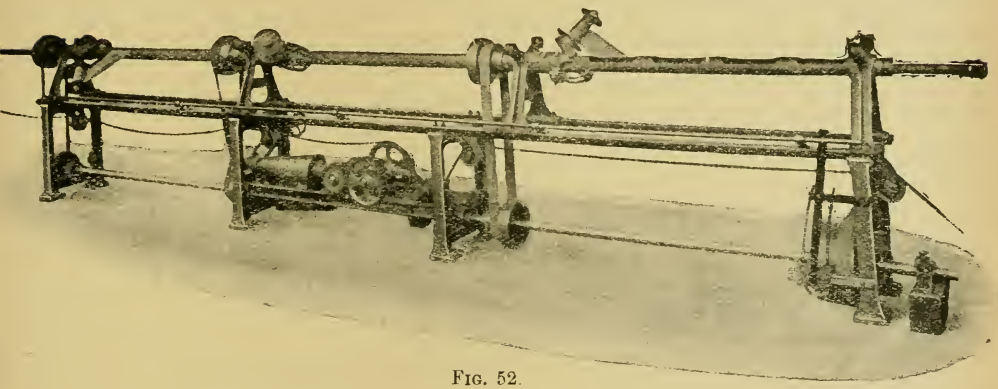


FIG. 52.

kind of hose is not wrapped, but is cured in chalk in the open. The proofed insertion cloth used in the manufacture of such hose must have powerful adhesive properties. This class of hose also can best be made on the hose machine nowadays, the separate coats being run out from it, through a nozzle shaped so as to form the imitation seams. In order to make the outside coating of rubber adhere firmly and closely to the insertion, the tubular mandrel as it comes through the machine is caused to travel a little faster than the rubber emerges from the nozzle.

Another article for which a great demand has arisen is the so-called

(*b*) **High-pressure hose (hose with braided insertion of hemp, cotton, or brass-wire).**—High pressure, or, as it is briefly called, braided hose, is the ideal hose for conveying water, and for conveying purposes in general. Over ordinary canvas insertion hose it has the great general advantage of being able to withstand enormously

high pressures, and can therefore be used of a relatively thinner substance than ordinary hose.

The process of manufacture of this high-pressure hose, the demand for which is constantly on the increase, is the same in principle as already described, with the exception that in place of the ordinary cotton insertion, an insertion made on the braiding machine is used. The method of procedure is as follows:—The tubular mandrel, covered with the inner coating of rubber, on leaving the hose machine, passes over a short conveyor belt, which serves rather the purpose of pushing the mandrel along, into the braiding machine (fig. 53). The speed of this machine is regulated in exact accordance with that of the hose machine behind it.

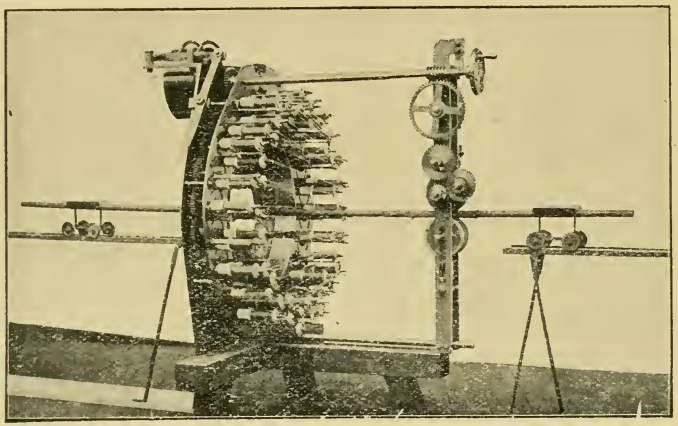


Fig. 53.

Between the hose machine and the braiding machine, and fitted on to the latter, is a small apparatus for covering the rubber coating on the mandrel with a rubber solution of medium thickness; during the braiding process which follows, this solution penetrates into the fibre of the hemp or cotton yarn, and brings about a very intimate union at every point. This small apparatus, as shown in fig. 54, consists of a small storage vessel with an automatic stirrer to prevent the solution from settling, and a mouthpiece connected with the outflow, beneath which a sheet-iron tray is fixed in order to catch any excess of solution. The mouthpiece or nozzle must be one of an interchangeable series, and is varied according to the size or outside diameter of the hose. Inside the nozzle is a jet for the supply of solution, and in front of this a celluloid spreading-knife is fixed. When the insertion has been braided on to the hose the mandrel passes through a larger solutioning apparatus, filled

with thicker solution, which is spread all round the insertion. In order to dry this off rapidly, by evaporating the benzine, a cast-iron heating jacket of about 100 mm. diameter is used, which can be provided with suitable nozzles at each end. The drying-jacket is heated to about 45° C. and the hose is driven through it—air being blown through at the same time by a fan. On leaving the drying cylinder the mandrel rests on the conveyor placed in front of it, and is carried forward at the same speed as it travels through the two machines, until the whole length of 40 metres has been coated with the inner coating, covered with the braided insertion, and spread with a coat of solution.

Three hands are, as a rule, sufficient for the whole of this piece of work: one to look after the hose machine, a girl to look to the

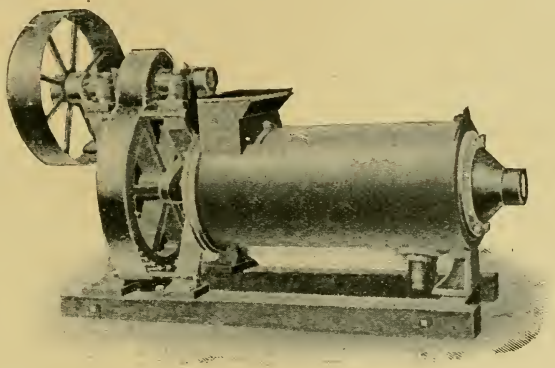


Fig. 54.

braiding machine, and the third to superintend the working of the whole plant.

This hose is generally made with two layers of braided insertion, often with several layers, the method of procedure being the same as above described, except that the hose machine runs empty in the intermediate stages. The outer coating of the hose is also run from the machine, and, as a rule, a slightly higher speed is given to the conveyor, so as to cause the layer of rubber to adhere firmly to the braiding. The braiding machines are mounted on movable trolleys which can be run along rails lying transversely in front of the hose machine, so that for the different sizes of hose, different braiding machines can be used in conjunction with a single hose machine. For diameters of from 10 to 28 mm. a 48-bobbin machine will do; for larger sizes, on the other hand, a machine with sixty bobbins should be used. It is not advisable to use the same braiding machine for all sizes, or the braiding will be in some cases

too close- or too wide-meshed, and too long in spite of the adjustable transport. On the other hand, if some of the bobbins be left out, the mesh becomes too open.

It is possible to make hose which will withstand a pressure of 200 atmospheres: in attempting this the number of ply of insertion must be correctly selected with reference to the internal diameter. For specially high pressure work it is advisable to carry out the penultimate braiding with brass wire, which is followed by a final braiding of hemp, this being in turn secured by a spiral wire.

(*c*) **Manufacture of "Spiral" Hose.**—The process is, in this case, the same as for ordinary hose, except that in arranging the spiral wire one must be guided by the purpose for which the hose is to be used, whether for suction or for high internal pressures, or whether it is to be adapted for both purposes, and the spiral wire must be arranged according to requirements.

In the case of hose up to 30 mm. in diameter, the inside coating is run directly on to the metal mandrel from the hose machine; in the case of the larger sizes, on the other hand, it is usual to proceed according to the older method, by laying the sheet round the mandrel, cutting down from end to end, pressing the seams well together, and covering them, as a safeguard, with a narrow strip of the same quality rubber, so that one may be doubly sure of the seams holding. If the hose is to be used as a suction hose, the spiral wire must be inserted immediately round the inside coating. On the other hand, when it is to be used as pressure hose it is an advantage to first of all roll the insertion down on to the inside coating, and then to slip the spiral on. The spiral is generally made of hard galvanised iron wire. Whereas the spiral used formerly to be run on to the hose by hand, special machines have come into use more recently, which coil the wire into suitable spirals. The size of the spiral is regulated by the adjustment of the matrices, so that it is only necessary to slip the ready-made spiral over the inner coating. This method is a far more rational as well as a more certain one than the old method. If the spiral is wound on to the inside coat the latter gets greatly twisted, and often torn, by the coiling on and expanding of the spiral. The ends of the spiral are soldered and held in position by a strip of unvulcanised rubber. On the top of the spiral there is always placed a coat of rubber, and over this the insertion. On the other hand, in the case of smooth-surface spiral hose, the interspaces between successive coils of the wire are filled up with strips of rubber, and then covered over. The making up is carried out in

the way previously described, according to the number of ply of insertion, and finally the hose is surrounded with the cover. In wrapping spiral tubing great care must be taken to see that all the parts are perfectly tightly pressed together, so that no blisters can be formed during vulcanisation. For this purpose a specially constructed machine is employed, the principle of which may be briefly explained. When the hose has been wrapped, it must be well corded with strong hempen cord. In a slide in front of the bench runs a winder, 2 metres long, with three cylinders, over which the cord runs with one turn round each, and is thereby braked. Above this the cord passes through a guide on to the hose, and, the mandrel having been set in motion, is allowed to run on to it under tension from the cylinders; thus directed by the guide it is laid tight in the interspaces between the successive turns of the spiral. As soon as the cord has reached the end of the winder this is moved forward along the slide according to the length of the hose, and there fixed, so that the cord can be wound round still further along. This operation can be performed with a good deal more power than by the workman passing the cord round his own body and exerting the braking force by leaning on it.

Vulcanisation follows the cording process, and is carried out in a long pipe, as in the case of all other hose. In conclusion, it is worth mentioning that after the hose has been vulcanised and unwrapped, it is best drawn off the mandrel by blowing compressed air between the mandrel and the hose through a conical nozzle. A few twists of the hose are sufficient to start it, and to enable it to be drawn off the mandrel. In dealing with strong spiral hose of large dimensions it is, however, necessary to make use of a forcing apparatus; this is brought into contact with one end of the hose, which it pushes along slightly towards the other end, at the same time giving it a twist against the tension of the spring. In this way hose up to 500 mm. in diameter can be easily drawn off. For large-size hose it is advisable to use as mandrels sheet-iron tubes, which can be allowed to spring, or be drawn inwards. The most suitable mandrels for hose manufacture are smooth-drawn steel tubes the ends of which are united by screw couplings. These tubes last much longer than brass mandrels, and on account of their absolutely smooth surface make the inner surface of the tube as smooth as glass. Steel tubes have yet another advantage over other metal mandrels, in that the rubber does not adhere so firmly to them.

(*d*) **Canvas Hose with Rubber Lining.**—Although the manufacture of canvas hose really constitutes an industry in itself, it

often happens that the proofing is carried out as a speciality in rubber-works. The manufacture may therefore be briefly dealt with so that the reader may acquire some slight acquaintance with the weaving of canvas hose. Power-driven iron looms have been in use now for about fifteen years for making canvas hose; the old wooden hand-looms, which were formerly to be found in every Thuringian peasant's dwelling, forming one branch of the cottage industry, have entirely disappeared. The manufacture is now carried out in factories only. Flax, cotton, or hemp yarn, spun in different ways according to the size of the hose to be woven, is used. Just as in the case of all other fabrics, a distinction is made in canvas hose between the warp and the weft threads. The former, which are twice as many as are required for the width of the hose,

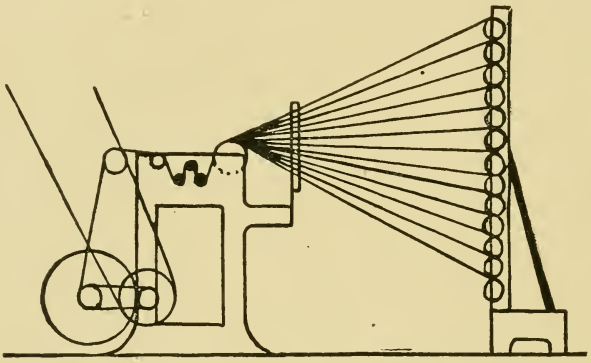


Fig. 55.

are beamed by means of a beaming machine (figs. 55 and 55A) on the warp beam. The mounting with the heddles, through which the separate threads are run, is also arranged exactly as in other looms; only the way in which the individual mountings move is different, the warp first separating into upper and under warp, the mountings then setting the upper warp so that the shuttle carries the thread through on the lathe, whereupon the under warp lifts and the weft thread is shot through in the same way. In this way the seamless hose fabric is produced. The finished tube is rolled up on a reel. About 300 metres can be made with one warp. The rough hose, if it is to be rubber-lined, is finished off in the following way:—

The hose is opened out by a machine (figs. 56 and 56A), and the tape necessary for pulling the rubber lining through is then drawn through it. The rubber lining, made on the tube machine, is partly cured for thirty minutes, then covered with solution, and drawn

through the hose by means of the tape already mentioned. The hose

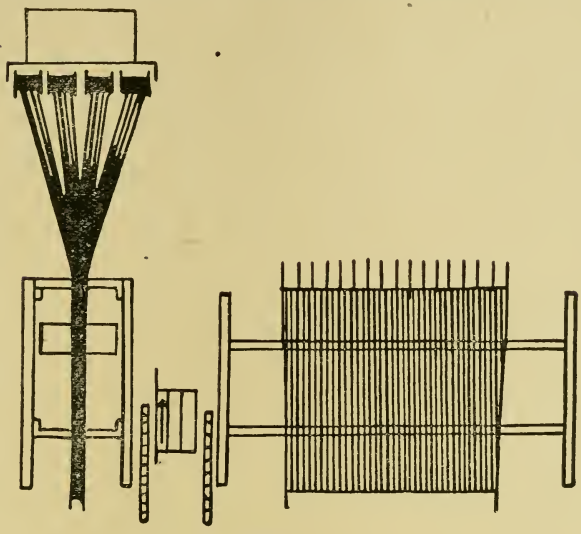


FIG. 55A.

is then fixed on to a vulcanising cone, and firmly clamped on the tube. The lower end is connected to the condensed steam pipe, and

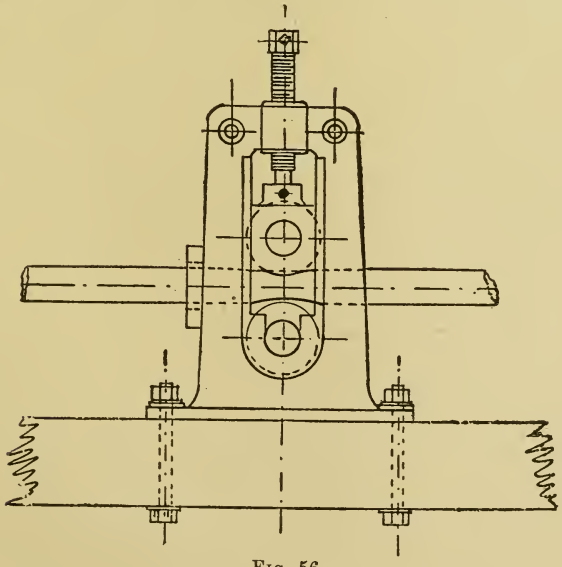


FIG. 56.

the final vulcanisation can then be begun. It is advisable to subject the hose to a steam pressure of about four to five atmospheres.

By the high pressure the hose-lining is forced firmly on to the

walls of the canvas hose, the solution penetrating the interstices, and the fabric and the rubber lining are thus intimately united. After lowering the steam pressure the hose is tested with a water pressure of 20 atmospheres, and hot air is then blown through it to thoroughly dry it. This method of lining hose with rubber is, however, being displaced by a new system which has important advantages over the old well-known method, in that there is no possibility of the hose-lining developing leaks. It is not always possible to avoid the formation of thin places in the walls of the

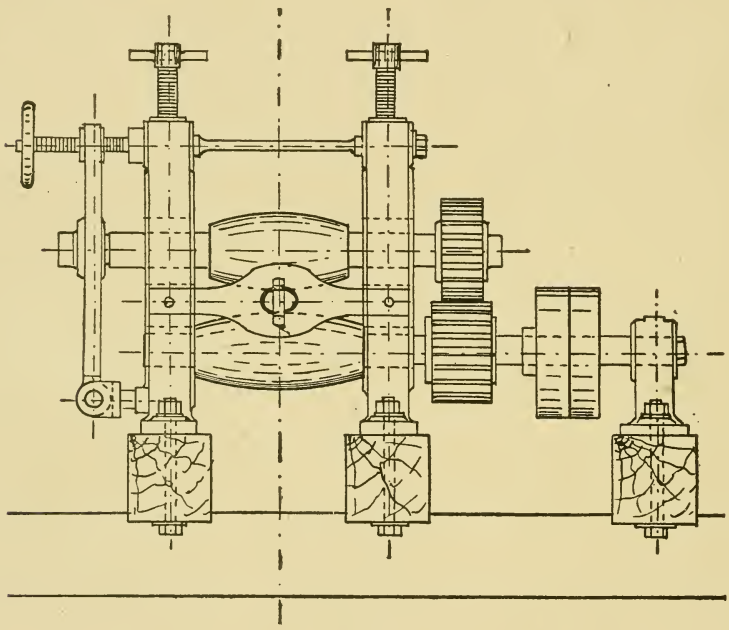


Fig. 56A.

rubber lining when drawn into the hose by the old method, and sometimes little grains or nibs of one or other of the ingredients, which have been introduced into the rubber in the course of mixing, get shot out of their places, leaving holes in the rubber where leakage may afterwards occur. In the new method the canvas hose (figs. 57 and 58) is stretched out in a heating chamber 30 metres long, arranged so as to be used in three sections. The fastening is by means of plates screwed on to the foundation plate by six screws. These plates are fixed to a movable frame, provided with a groove, which can be so adjusted by turning the screws that the hose inside the chamber is tightly stretched. The wires, to which are attached the rubber brushes, the object of which is to draw the

solution evenly along the tube, are run through the hose, and pass over rollers at either end of the apparatus. These rollers can be

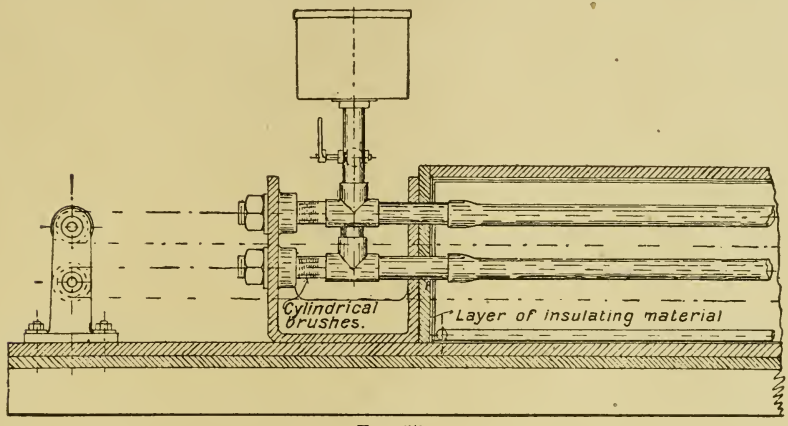


FIG. 57.

mechanically driven in either direction. Between the rollers and the chamber is introduced a piece of apparatus which is connected

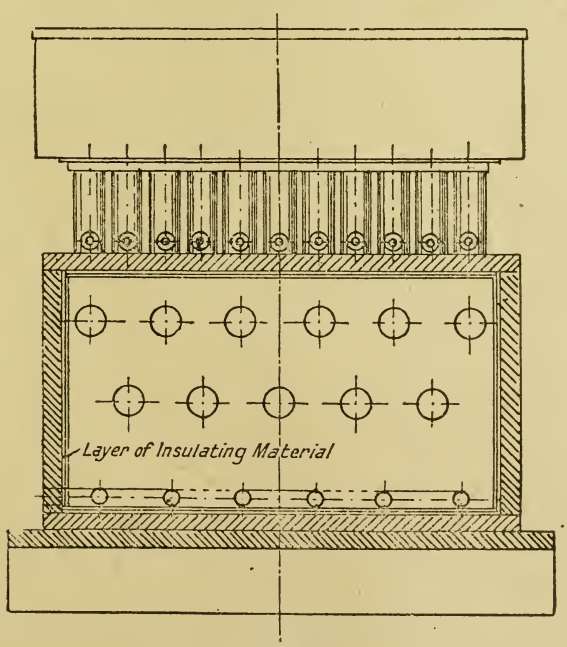


FIG. 58.

to the hose, and into which the amount of solution necessary to put an inner coating of rubber on hose of that particular diameter is

forced from the solution-holder by means of compressed air. When the separate boxes are full the driving mechanism is set in motion, and the solution is drawn through the hose by means of the brushes; the brushes are given a rotary motion, and so spread the solution evenly over the inner surface of the hose. The brush, on passing through the hose, carries the excess of solution into the apparatus at the opposite end, which now gets filled with solution, as previously described. Before the brush travels back through the hose in the opposite direction, hot air is blown through the hose, and this, in combination with the internal heat of the chamber, causes the solvent to evaporate. This process must be repeated until the desired thickness of rubber lining is attained. When that is the case, the chamber is closed at both ends and the vulcanisation is proceeded with. Vulcanisation is effected by means of hot air, which is led into the chamber at one end, and at the other end is driven through the hose by means of fans. It takes about five hours to proof 30 metres of hose to a thickness of 1½ to 2 mm., and the vulcanisation occupies another forty minutes at 145° C. It is not advisable to cure the hose on the cone with direct steam; by that means the solution gets forced too far into the meshes of the fabric and the hose does not turn out perfectly smooth inside. The dimensions of the 5 cm. long brush-rollers, as well as those of the steel discs, with rounded edges, behind them, are determined by the internal diameter of the hose.

In spite of the consumption of solvent (benzine) this process works out cheaper, for lower quality mixings can be used and thinner coats can be put on, and still the strength of the hose will be considerably greater than that of similar hose made by the older process, while the finished article will be lighter in weight and more pliable.

2. Moulded Goods, and the Manufacture of Hollow Articles such as Balls and Toys.—Another department of rubber-goods manufacture is that which deals with the manufacture of articles vulcanised in moulds, of which one has to distinguish between two kinds, viz. solid and hollow articles.

The manufacture of solid moulded goods is fairly simple. The articles are built up out of unvulcanised sheet rubber, until they fill the mould; they are then subjected to a preliminary pressing, the waste which is squeezed out being removed, and the articles are then lightly powdered (with French chalk, etc.) and cured in the tightly-closed moulds. It is most important that no air should get shut in, but that it should all be forced out while the mould is

being closed up. For this reason it is advisable to use moulds made in several parts, but such moulds have also a special value when the goods come to be taken out after vulcanisation. Articles with metal, wood or cloth cores—*e.g.*, a ball valve—are prepared in the following way so as to keep the core central:—

The core, after being well-roughened, is given a coat of durable quick-curing solution, and when this is dry a sheet of rubber is laid on it and cut in the form of an 8 round the core, so as to obtain a completely closed layer of rubber. The cut edges having been well pressed together, the process is repeated until the thickness of the superimposed layers of rubber is equal to that of the finished ball. In carrying out this process it is necessary to arrange the 8-shaped seams in such a way that those of successive layers do not lie on top of one another. A ball prepared in this way possesses the advantage of having its cores already in as central a position as possible. After the preliminary pressing, vulcanisation can be begun in the moulds, which must be clamped up tightly for the purpose. Smaller balls can be made up in another way, viz. by cutting a sheet of rubber into strips and winding these round the core. In doing this it often happens that the core gets shifted through the strips not being laid on evenly, or the core may be loose inside its rubber covering.

For the manufacture of rubber stoppers, cord of a suitable size is run on the tube machine, and is then cut into pieces of the right weight and pressed into moulds. In dealing with moulded goods in particular the exact weight of rubber for each article, *plus* 2 or 3 per cent. to allow for that which is squeezed out under the pressure put on the mould, should be taken. In order to avoid turning out faulty work on vulcanisation, care must be taken that all sheet, or shaped-pieces made on the various tube machines, are free from air-bubbles. Whereas small moulds are subjected to great pressure by clamping them tightly in iron clips, and cured either in a steam heater or in the sulphur bath, other moulded goods, such as billiard-strip, deckle-straps, pulsometer valves, etc., are vulcanised under great pressure in a vulcanising press. For larger moulded goods with stout walls the use of hydraulic autoclave presses for vulcanisation is to be recommended: this form of apparatus will be specially referred to in the chapter on pneumatic tyres. In the case of goods to be delivered in long lengths—*e.g.*, deckle-strap, billiard-strip, moulded cord, cab-tyre—vulcanisation must be carried out bit by bit. For this reason the mould should in all cases project at least 20 cm. from

each end of the press. Vulcanisation of the first length is commenced with one end of the mould closed, and only one end visible outside the press. In proceeding with the further vulcanisations one end-plate is unscrewed, and the mould is allowed to project from the press at both ends, so that the vulcanised end can be slipped out of the mould from time to time. But in order that the rubber behind it, which has still to be vulcanised, may not move out of position, the finished portion projecting from the mould is firmly bound on, and is thus prevented from slipping out. Deckle-straps are made in the same way, and are then made endless by vulcanising the ends together in a convenient small mould. All joints should be carefully bevelled. Air-markings may result if the mould is not properly closed, or if the air cannot get away easily; also if the deckle is not withdrawn quickly enough when the mould is opened, and air-spaces are formed between the mould and the rubber as the latter cools. Poor, soft qualities, and rubber which has been worked too much, also give rise to air-markings which may be recognised by their considerable depth. Special care should always be taken to have the mould properly cleaned throughout.

The second kind of moulded article is the hollow article. Such articles are either prepared on mandrels, which shape the inside of the article, or are inflated by means of some gas, as in the case of balls and dolls. In each case these articles are made by the union of two or more sections cut out of sheet. This branch of manufacture is carried out essentially by hand labour, though in the case of rubber balls machines are also used to cut or punch out the separate sections. Balls are generally made up of from four to six pieces united along their edges by means of solution. Special machines which effect both the punching out and the making up are also in use, and there are also a number of patented processes in practical operation.

Balls are made up, as already stated, chiefly by hand labour. On the inside of one of the sections is fixed a plug of lightly vulcanised rubber, the object of which will be explained later on. Before the ball is quite closed up, a quantity of ammonium carbonate, varying from 8 to 45 grams, is put in, the amount depending upon the size of the ball, and also upon the tenacity of the rubber mixing. Other methods of inflating balls, depending upon the introduction into the ball of substances which on being heated evolve nitrogen, are in use, but up to the present no method of inflating balls which would simplify existing processes of manufacture by doing away with the need for the use of plugs, and

with the necessity for inflating the balls after vulcanisation, has proved to be adapted to practical use.

Another process which may be employed for inflating hollow articles consists in the use of ammonium nitrite, which, as is well known, is decomposed, on heating, into nitrogen and water, according to the equation—

$$NH_4 \cdot NO_2 = 2H_2O + N_2.$$

The ammonium nitrite may be prepared *in situ*, by the action of alkali nitrite on ammonium chloride, in accordance with the equation—

$$NH_4 \cdot Cl + NaNO_2 = NaCl + NH_4 \cdot NO_2.$$

The most convenient method of inflation is to utilise the production of CO_2 from carbonates. Nitrogen can also be prepared from chloride of lime and ammonia, and ammonium carbonate may be used instead of the latter. In mixings which have not the proper composition, and especially if the rubber has not been worked until perfectly homogeneous, and in which therefore the micro-porosity of the rubber is greater than it should be, ammonia may easily pass through the walls of the article, or fill the pores and decompose the rubber. In this place a crystal of ammonia is formed on the outside of the ball, and the gases and air are allowed to escape. It is therefore considered desirable to add to ball mixings a quantity of pitch, or a mixture of ozokerite and pitch. The use of finely-ground, dry, pulverised waste should not be permitted. If such be used there will always be produced a number of spots which are permeable to air or other gases, whereas none of these can be noticed if reclaimed rubber and pitch be used. The pitch certainly darkens the colour of the rubber a little, but in the case of painted balls that is of no consequence. The following mixings are some which have been used with good results:—

RUBBER BALLS.

(1)	Mozambique	5,000	gms.
	Massai	5,000	,,
	Sulphur	1,200	,,
	Zinc white	12,000	,,
	Whiting	15,000	,,
	Pitch	300	,,
(2)	Upper Congo	4,500	,,
	Nicaragua	5,500	,,
	Sulphur	12,000	,,
	Reclaimed	6,000	,,
	Lithopone	12,000	gms.
	Talite	10,000	,,
	Pitch	300	,,
(3)	West Indian	10,000	,,
	Ozokerite	400	,,
	Sulphur	1,200	,,
	Reclaimed	8,000	,,
	Zinc white	12,000	,,
	Whiting	15,000	,,
	Pitch	200	,,

The manufacture of hollow rubber toys, such as dolls and animals, is carried out in the same way, the separate sections being

cut out of sheet, and joined together in the form of the portion to be reproduced. They are made up in the same way as balls, but it is preferable to use water as an inflating agent during vulcanisation, or else capsules of gelatine containing sodium bicarbonate and tartaric acid, from which mixture carbon dioxide is evolved.

Vulcanisation proceeds exactly in the same way as in the case of other moulded goods, but the rise of steam pressure should be as rapid as possible, and care should be taken that the temperature and pressure do not recede during the process, so that the hollow articles may not drop in. Of late, ball-presses (fig. 59) have been coming

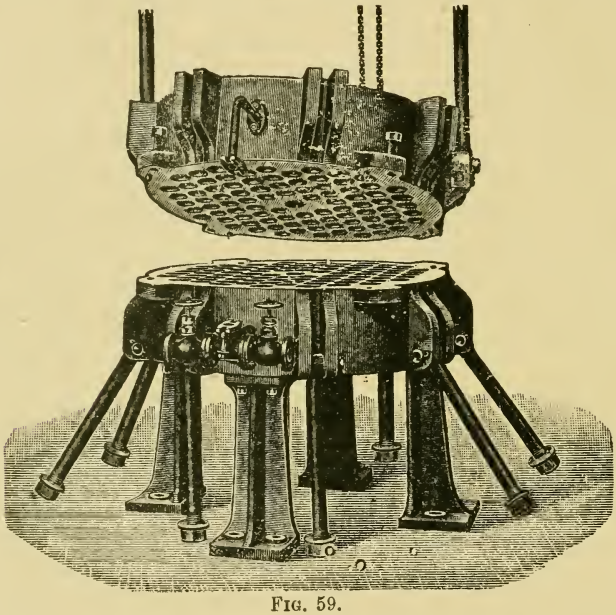


Fig. 59.

into use in place of single moulds, for curing balls both hollow and solid, of reasonably small dimensions, say up to $2\frac{1}{2}$ inches in diameter; with such an arrangement as many as two hundred balls can be cured in a single operation. The simplicity of handling and working this apparatus, together with the fact that means are provided for cooling down rapidly by a flow of cold water through the press-plates, constitute very great advantages. The moulds are opened while they are being vigorously cooled down; by this means the gases present in the ball under considerable pressure are prevented from blowing it out still further, and, on the other hand, from contracting owing to the fall of temperature. For this reason it is also necessary to re-inflate the ball after vulcanisation; this is

only done on the grounds already given, and it is incorrect to assume that all gases diffuse through the ball. After the inflating gases have been removed from the ball it is filled by means of compressed air, which should be as cold as possible, the object of the plug previously referred to being to close up the hole made in it by the hollow needle when the latter is withdrawn. For safety's sake it is best to push a small piece of rubber, soaked in turpentine, into the plug in addition.

In toys the after-inflation is unnecessary, because they are provided with air-valves. The holes into which these are fitted are drilled out on a drilling machine.

Balls and toys are painted by hand. In the case of balls the ground-work and lining can be put in with the aid of a small painting apparatus. The arrangement is extremely simple; the ball, resting on a disc, is rotated whilst a fixed brush marks the lines according to the position in which it is put and the colour with which it is filled. The pictures on the balls are put on with transfers.

The mixings used for the manufacture of dolls should be very soft and elastic, since they must be able to take the impression of the sharpest intricacies of the various moulds. The following may be given as examples:—

RUBBER DOLLS.

(1)			(2)		
Columbian	6,000	gms.	Lopori	6,000	gms.
Sulphur	1,400	,,	Columbian	4,000	,,
Ceara	4,000	,,	Golden sulphide	3,000	,,
Zinc white	10,000	,,	Whiting	8,000	,,
Whiting	8,000	,,	China-clay	4,000	,,
China-clay	4,000	,,			
Paraffin wax	250	,,			

3. **Manufacture of Seamless Tubing and Shaped Cord.**—In the manufacture of these goods the tube machine depicted in fig. 60 occupies an all-important position, and a very great variety of articles can be produced by means of it according to the die employed. The machine consists of the cylindrical casing, which can be heated, enclosing the screw, and the box, in which a spindle is fixed; this spindle, the form and size of which depend on the article being made, can be centred by means of set-screws, and its thickness corresponds to the internal diameter of the tubing to be made. In addition, we have at the end the die with a circular hole which determines the outside diameter of the tube. If the spindle be removed the machine produces a cord, which may be of circular section or angular, according to the die employed. The machine

works as follows:—The mixed rubber is warmed up and run into thin sheets which are filled into the hopper fitted over the cylinder at the after-end of the screw (this hopper is, in some forms of machine, substituted by feeding-rolls), and is then forced through the screw towards the box in the front. It will be clear that during the operation the rubber mass is powerfully kneaded, and a breaking-down of the rubber molecule may readily occur—first, if the cylinder be too strongly heated; and secondly, if its length be too great, since the mass is then worked for too long a time before reaching the die. Tube machines with short cylinders and powerful screws of great depth are to be preferred for the production of a suitable pressure. The extent to which the machine must be heated up in order to obtain a smooth surface — the so-called "mirror" (*Spiegel*)— is greater or less according to the quality of the rubber mixing. This warming-up refers less to the cylinder than to the box of the machine, and better results are obtained by using a gently-heated cylinder and a hot box than if the reverse plan be adopted. Very tough qualities, which cannot be run smoothly, are mixed with from 1 to 5 per cent. of vaseline or paraffin wax; surprising results are obtained in this way. The cord or tube leaving the machine passes through French chalk, carbon black, or other powder, according to its colour, and is either run into the vulcanising chamber in front of the machine, or on to wooden trays. In the latter case it may be either worked up for use in the manufacture of moulded goods, or vulcanised direct. These articles are laid in French chalk just as they are made, the chalk serving to keep them in shape and prevent them from getting flattened, and also to prevent the direct penetration of moisture; the goods must therefore be made from qualities which can be cured in the open without becoming rough on the surface. Many qualities, especially those which contain soft rubbers and a large proportion of softening ingredients, such as vaseline, paraffin wax,

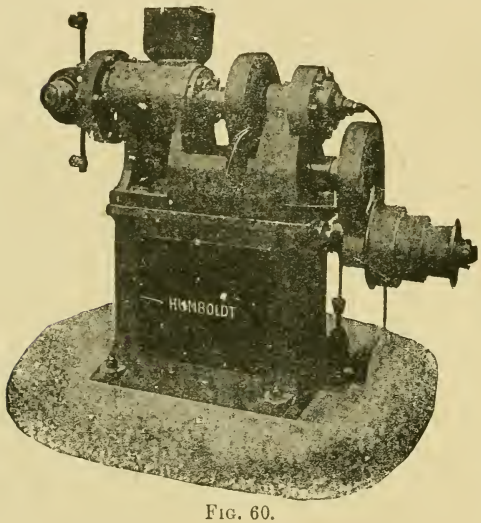


Fig. 60.

fatty substitute, etc., need a suitable addition of magnesia usta to enable them to be cured in chalk in the open; only those makes of magnesia which consist of oxide alone, and do not contain carbonate or hydrate, are to be recommended for this purpose.

In the case of large cord care must be taken to have a perfectly homogeneous mixing; otherwise these goods become porous from the centre outwards, a result produced in many cases by faults in mixing or by the use of unsuitable ingredients.

Linings for canvas hose are, as already mentioned, also made on the tube machine. For this kind of tubing either a machine with a hollow screw or one with a transverse end is used, so that chalk can be introduced by blowing it through by means of an air-blower attached to the machine. Inner tubes are run on the machine in a similar manner. In order to be able to regulate the pressure of the rubber, a cock is fitted into the box of the machine through which the excess of rubber is allowed to pass out; this is a point which must be specially observed if one desires to produce tubing with uniform thickness of wall.

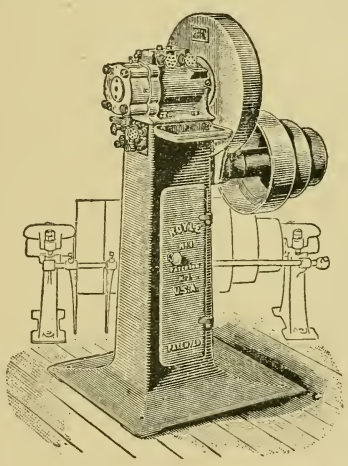


Fig. 61.

For the manufacture of flower-tubing (covering for the stems of artificial flowers) machines are used with very small cylinders and with a special arrangement of the box (fig. 61), enabling tubes up to three in number to be run at the same time. The use of hydraulic pressure in tube machines does not seem to have met with approval. Experiments initiated some years ago have not yielded satisfactory results, for it is hardly possible to keep the temperature of the rubber constant, and defective places are easily produced. On the other hand, there has recently been a leaning towards two-spindled machines, which consist, in principle, of two tube machines fixed opposite to one another, and united in the middle by the box, so that the rubber is forced both from the right and from the left into the box and die.

4. **Preparation of Sheet for "Mechanicals."**—For the manufacture of these articles, which constitutes an important branch of the rubber industry, calendered sheet and the proofed fabrics for insertion form the central point, as the basis for making up. Packing-sheet

with insertion is generally prepared by rolling the rubber coating on to the proofed fabric. This process can be simplified by uniting the proofed insertion and the coat of rubber direct while the latter is being run on the calenders, thus preparing the finished

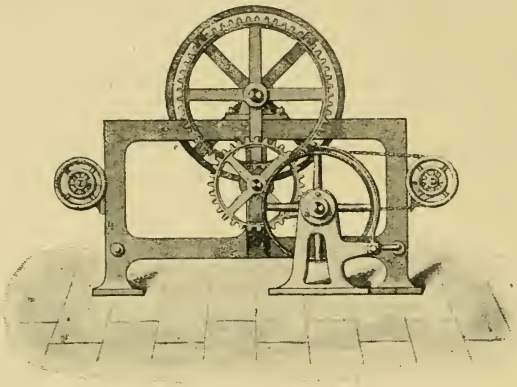


Fig. 62, A.

sheet, firmly doubled, in the same time as would be necessary merely to run the coating of rubber. The whole process is exactly similar to that employed in the preparation of sheet rubber which has to be doubled, and has been fully dealt with in the chapter on the calenders. Before curing, the finished sheet is tightly wrapped

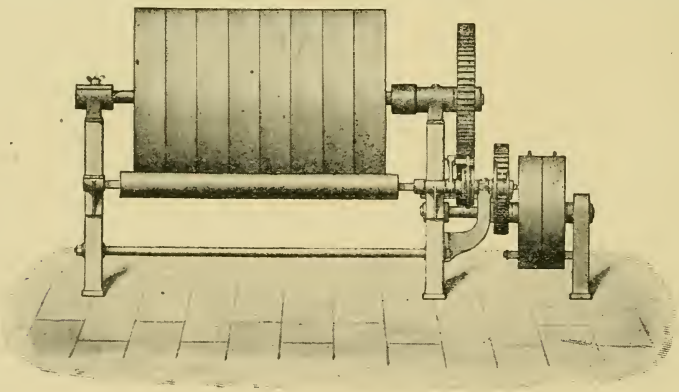


Fig. 62, B.

between cloths on a wrapping-machine (of which fig. 62, A and B, illustrate an improved form), in order to prevent its blistering, and to cause the various layers of rubber and insertion to become firmly united during vulcanisation. Packing-sheet may also be cured under the press, but the cost of vulcanisation then comes out considerably higher.

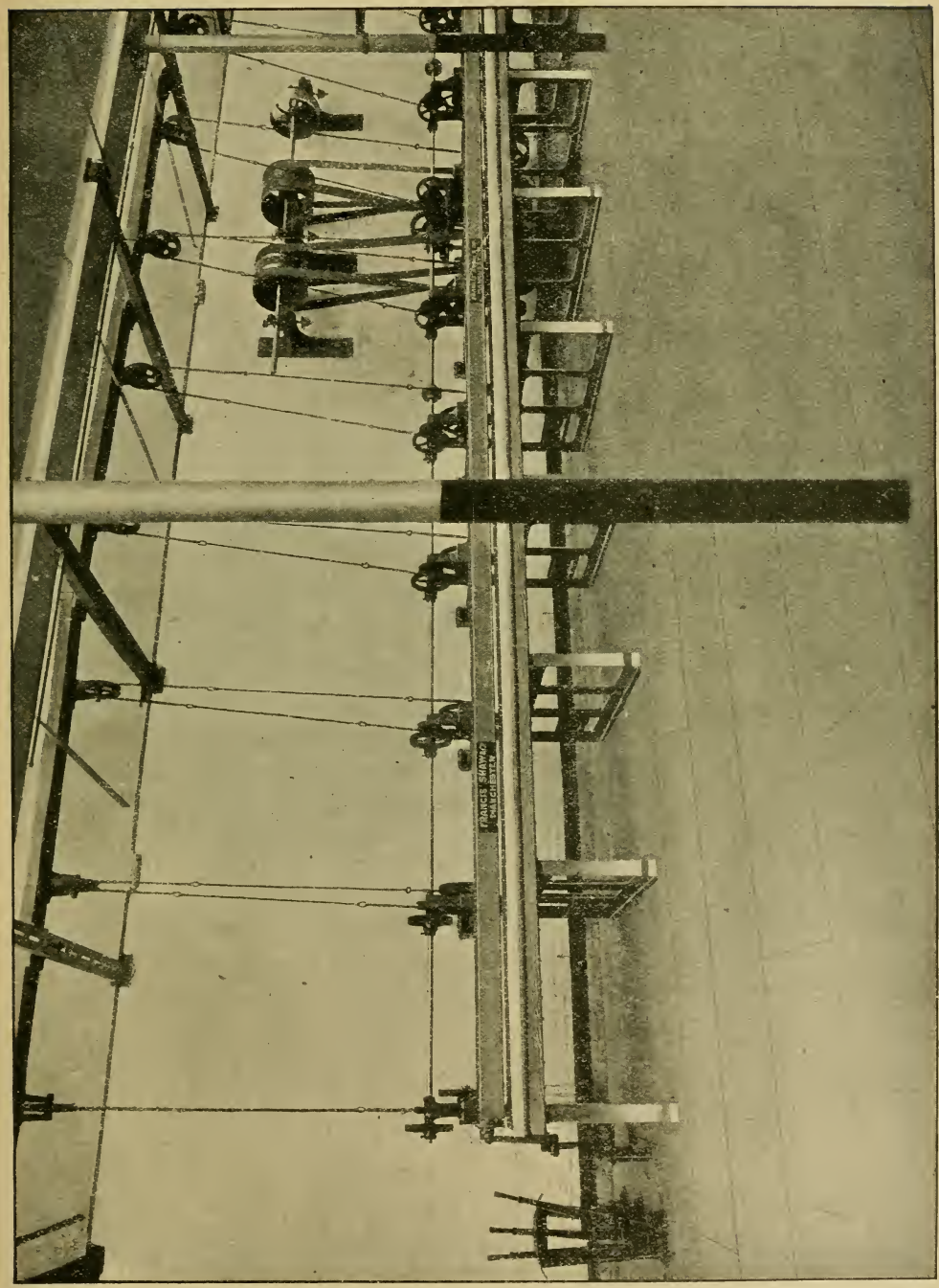


FIG. 63.

Manhole washers, and flat rings made up of strips, are cut from uncured sheet by means of a band saw, and the strips joined up together, covered with cloth where necessary, and cured on sheet-iron moulds. The manufacture of round cord is carried out cheapest and best by means of a machine made by Francis Shaw of Manchester (fig. 63). The separate sheets, united with their inser-

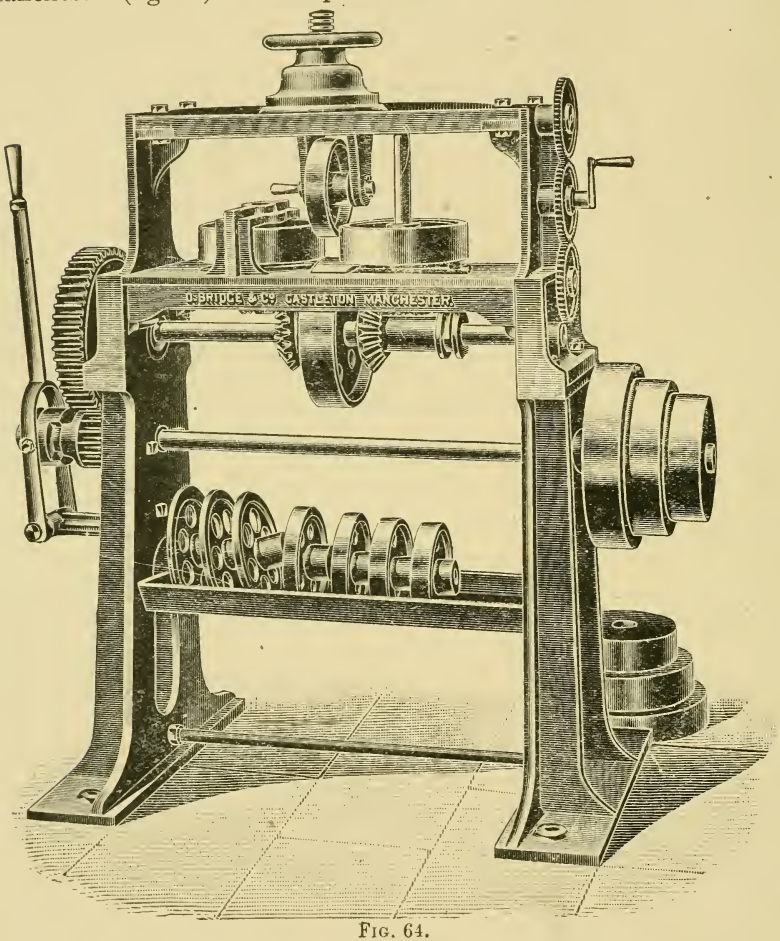


Fig. 64.

tions, are rolled up, and any number of such strips up to twelve are put under the rolling machine, formed of two bench-tops. The upper bench-top, tilting increasingly as it advances, presses on the strips in its forward motion and rolls them into the form of round cord; insertion and covering can be rolled up in one operation. Where smooth cord is desired the covering is left out, and, if necessary, a layer of rubber is run on to the cord by means of

the tube machine. The cord is vulcanised in a straight length, in a hose-heater, after having been previously wrapped in the same machine. Square and flat Tuck's cord is first made up in the form of round cord in the same way, and is afterwards passed through the shaping-machine (fig. 64) and pressed into shape. This machine possesses the great advantage over the ordinary grooved rolls, that by means of it cord of any dimensions can be made by merely changing the upper wheel. Tube-rings and similar articles are made of the required size on the tube machine, and are then drawn on to mandrels of corresponding size, wrapped in cloths, and vulcanised.

5. Press-cured Goods.—Under this heading press-cured sheets and pump valves first of all claim our attention. These articles are made by doubling sheet up to the required thickness, care being taken to get rid of all air-bubbles, and then cutting it down to the required sizes. Lengths of 3 metres by 1½ metre wide are what are generally asked for in the case of press-cured sheet, and such sheet is built up on the press-table and vulcanised in one piece of that size. In the case of circular valves, and valves of other shapes, planed wrought-iron rings and frames of corresponding shapes are used; by these the rubber is supported during vulcanisation, which is carried out under suitable pressure. In calculating the sizes of moulds it must be remembered that rubber contracts somewhat on vulcanisation, as a result of the shrinkage of the raw rubber and the way in which it has been stretched by the processes previous to vulcanisation. Pure qualities contract to the extent of from 2·65 to 2·9 per cent., lower qualities proportionately less, and the latter decrease in thickness, whereas the former thicken up slightly; in preparing moulds these facts must be specially taken into consideration. Another article which is cured under the press is dealt with in the following section.

6. Rubber Belting.—The manufacture of this special article necessitates special machinery, if it is to be carried out in a rational manner and durable, serviceable goods are to be produced. The belting is prepared in the following way:—The cotton fabric, spread on the calenders, and into which a highly adhesive layer of rubber is frictioned, is folded, on a folding machine, into belts of the requisite thickness and the desired number of ply. The excess of fabric is cut off on the machine; or, if it is too narrow, another piece is stuck on. In this way a considerably more even product is obtained than by hand-folding, a process in which, for example, it is impossible to get rid of air-blisters. Unfortunately, German manufacturers are

not yet very familiar with this machine, and therefore prefer hand-work. When the insertion has been folded the belt is run through the belting calenders (fig. 65) in order to press it and straighten it

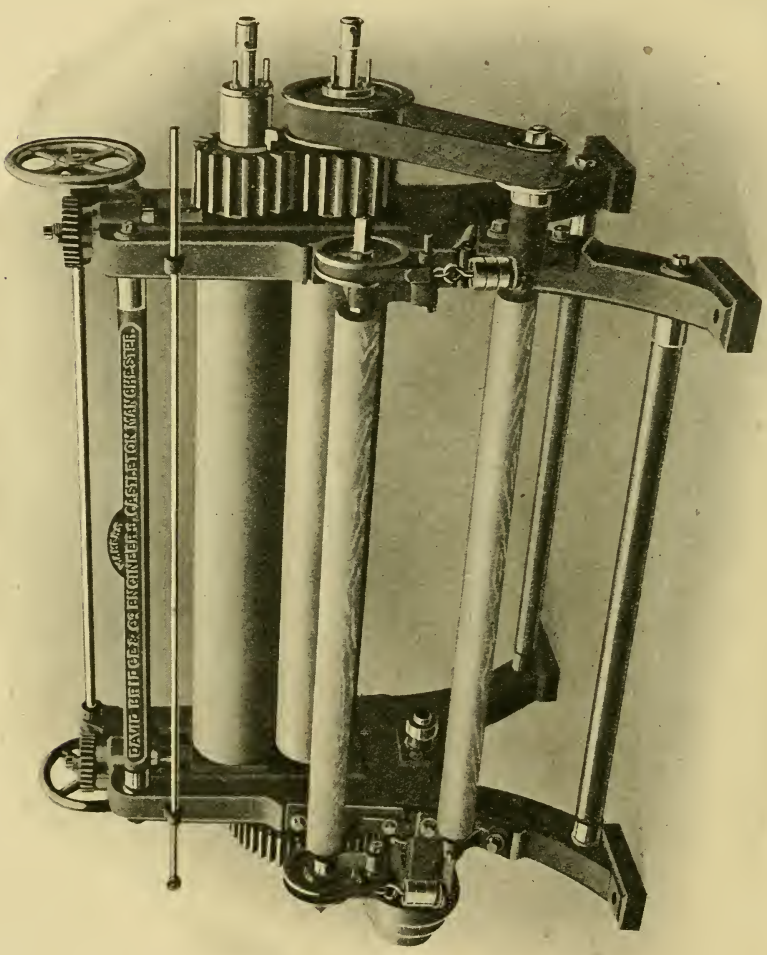


Fig. 65.

out. If the method of making up necessitates it, a covering sheet of rubber may now be put on, but on properly spread cotton fabric this is not at all necessary. The belting is vulcanised either with squared edges, in moulds, or with rounded edges, free under the

hydraulic press. In order to prevent the belting from stretching while in use, it is necessary to stretch it while it is under the press being cured, and this also is done by means of hydraulic power, the necessary apparatus being attached to the press. To produce a good solid article a pressure of at least 20 kilograms per sq. cm. should be put on the belting by means of the press while it is being cured, and the temperature should not be raised above 140° C. so that the fabric may not be weakened. This temperature is quite high enough to bring about rapid vulcanisation with the particular mixing employed, which contains litharge, and to render the article firm and stiff; at higher temperatures the belting would become too hard. A particularly suitable mixing is one of the following composition:—

West Indian	10,000 gms.	*Sheet for cover.*	
Sulphur	1,500 ,,	Congo	10,000 gms.
Litharge	1,800 ,,	Sulphur	1,500 ,,
Whiting	15,000 ,,	Litharge	1,000 ,,
Pitch	1,000 ,,	Reclaimed waste	10,000 ,,
Barytes	5,000 ,,	Whiting	15,000 ,,
Carbon black	200 ,,	Talite	7,500 ,,

It is advisable to employ considerable hydraulic pressure, because the fabric, although previously dried, always contains a certain amount of moisture, which is given off in the form of steam during vulcanisation, and may be the cause of the belting splitting into layers later on.

7. Rubber Rollers. — The preparation of rubber rollers is a department of manufacture demanding great experience and knowledge, for the uses of rubber rollers are so diverse that a particular method of manufacture and a special mixing are demanded for each particular class. In the case of all rollers, however, there is one point of great importance which is seldom observed, viz. that the workshop should be free from dust and kept at a uniform temperature. Convenient lifting apparatus (overhead travelling cranes) should be provided, so that the rollers, which are often very heavy, may be easily handled. The stands upon which the rollers are supported, as well as the wrapping apparatus, are made of galvanised ironwork. Wooden supports and trestles should be avoided as far as possible. Paper rollers—so called "wet-press" rollers—which need special treatment on account of their size, constitute a special department. All rollers have iron cores, which may be either solid castings, or made hollow of sheet iron, according to what the roller is to be used for, or, as in wringer rollers, the core may be simply a turned iron spindle. Large solid cast-iron cores

are not well adapted for covering with rubber, on account of the unevenness of the heating-up.

Before anything further is done with the core it must be warmed up in order to remove any traces of moisture that may be present. After this operation has been carried out—it may be done in a hot-air oven, or over a charcoal fire, etc.—the iron roller is cleaned. Any pores found in it must be either plugged or filled with lead, to prevent the formation of air-bells between the inner coat of rubber and the iron core. If the rollers to be covered are large hollow ones it is advisable to connect them up with a steam pipe so that they can be kept warm while the roller is being made up; by so doing even a very slight formation of air-bubbles is provided against. When the core has been examined it is washed with benzine, and is then repeatedly brushed over with hard-rubber solution in thin layers. The coating of hard rubber to be put on the top of this should be hard and tough in order to unite well with the metal; a rubber insufficiently so might result in the rubber coming away from the iron, a tendency which is assisted by the unequal expansions of rubber and iron within the limits of temperature dealt with. The layer of hard rubber which is put round this innermost coating, and the thickness of which varies according to circumstances, sometimes reaching as much as 15 mm., is in its turn covered by a mass of hard rubber of a firmer quality, to form the junction with the soft outer layer of rubber, and serve as a firm foundation for it. Single sheets of rubber are doubled up to about 1·5 mm. thick, and are then worked on with a roller, and the seams pressed well together. It is best to dry-wrap the hard-rubber layer firmly over-night, and to prick any bubbles which are evident on the following day. A preliminary heating of the hard-rubber layer is not necessary in good work. The process of doing so often brings about a loosening of the innermost coating from the iron during the second vulcanisation. The best way of rolling on the outer coatings is without doubt in the form of sheet which has been carefully crossed and doubled up to 1·5 mm. in thickness. The method according to which the layers of rubber are put on in the form of a spiral band is uncertain in its results.

In doubling the sheets and rolling the different layers of rubber on to the core, the roller should be kept continually at a uniform temperature, so that any air-bubbles can be seen to be driven off. When completely built up the roller is wrapped, on the power-driven wrapping apparatus provided for the purpose, in a close-woven cotton fabric, capable of standing a great strain, and is then

first heated up very gradually during three to six hours, according to the size of the roller or the thickness of rubber, being afterwards slowly vulcanised at 135° C. for from eight to twelve hours. The temperature should not, however, be allowed to drop before vulcanisation sets in, or the outer coatings may become porous or spongy, places of unequal hardness being formed. After vulcanisation the roller should be allowed twelve hours to cool down, or more, according to its size, after which it can be unwrapped and turned up and buffed on the lathe.

It may here be mentioned that the process of manufacture has

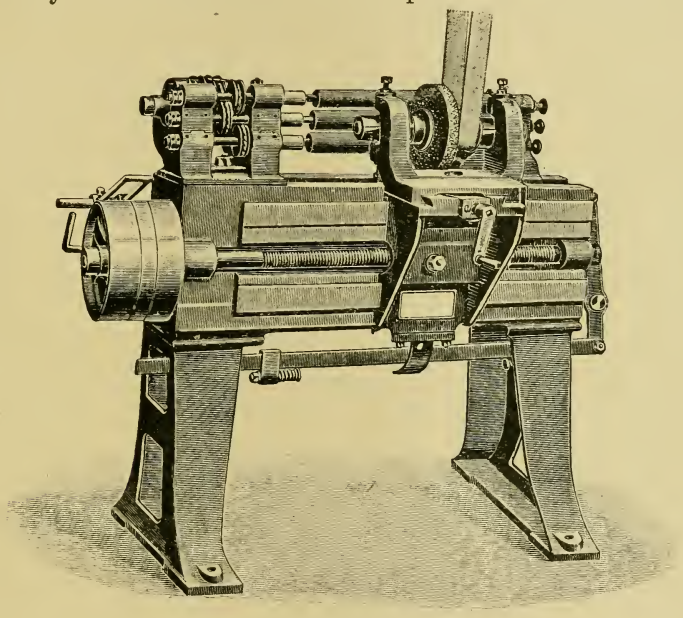


Fig. 66.

latterly been rendered much simpler and quicker by suitable additions of magnesia to roller mixings. The magnesia is added to the hard rubber as well as to the soft rubber of the roller covering, and its use is quite permissible in rollers which are to be used in the manufacture of food stuffs.

In the case of large rollers the lathe-tool is used until the roller has been turned quite true, when the buffing is finished off with an emery-wheel; wringer-rollers, on the other hand, are finished off direct upon specially constructed buffing lathes, on which three articles can be buffed at a time. Fig. 66 illustrates one of the newest forms of this machine.

The compositions of the mixings used are determined by the

requirements which they have to satisfy. The following are a few examples:—

Hard rubber inside-coating for hard-press rollers.

(1) Congo	6,000	gms.
Canvas waste	2,000	,,
Reclaimed	3,000	,,
Sulphur	1,500	,,
Magnesia usta	1,250	,,
Litharge	1,000	,,
Barytes	5,000	,,
Pitch	500	,,
(2) Congo	10,000	,,
Reclaimed	10,000	,,
Sulphur	5,000	,,
Magnesia usta	1,000	,,
Litharge	2,000	,,

Covering sheet.

(1) Para	10,000	,,
Zinc white	8,000	,,
Barytes	2,000	,,
Sulphur	1,000	,,
Magnesia usta	300	,,
(2) Para	6,000	,,
Lopori	4,000	,,
Golden sulphide (17 %)	3,000	,,
Barytes	7,000	,,
Magnesia usta	250	,,

Leather press-rollers.

(1) Para	10,000	,,
Pitch preparation	1,000	,,
Zinc white	10,000	,,
Litharge	3,500	,,

Leather press rollers—cont.

Barytes	6,000	gms.
Sulphur	1,000	,,
(2) Para	5,000	,,
Mozambique	5,000	,,
Litharge	4,000	,,
Barytes	7,000	,,
Sulphur	1,500	,,
Ceresin	500	,,

Lacquering rollers, for lacquer and turpentine.

(1) Para	10,000	gms.
Sulphur	900	,,
Magnesia usta	150	,,
(2) Para	10,000	,,
Golden sulphide	1,100	,,
Magnesia usta	100	,,
Vermilion	600	,,
(3) Para	1,000	,,
Litharge	3,500	,,
Sulphur	800	,,
Pitch	500	,,

Sleeves for printing-machines.

Kassai (Congo)	10,000	,,
Substitute, white	6,000	,,
Zinc white	10,000	,,
Barytes	3,000	,,
Talite	5,000	,,
Sulphur	1,500	,,
Magnesia usta	200	,,
Paraffin wax	250	,,

8. Pneumatic Inner Tubes and Tyres, Pedal and Brake Rubbers and Cab Tyres.—In the manufacture of inner tubes, which can be carried out with comparatively simple plant, attention must be chiefly directed towards producing mixings which are absolutely clean and free from grit. Such a mixing for ordinary inner tubes would consist of rubber, which has been very carefully washed, and sulphur; for second qualities a cheaper compound can be used, but then it becomes a question of reducing the porosity of the rubber to a minimum. Mixings containing ingredients which when added on the mixing rolls are likely to flake, or to become granular, should be rejected; on the other hand, the following mixings have been tried and can be recommended for the purpose:—

A. (suitable for motor-cycle inner tubes only).		
Para	10,000	gms.
Sulphur	900	,,
Pitch	50	,,
B. Para	5,000	,,
Columbian	5,000	,,
Sulphur	1,250	gms.
Pitch	75	,,
C. Columbian	5,000	,,
Manaos	5,000	,,
Sulphur	1,000	,,
Substitute	4,000	,,
Pitch	200	,,

Inner tubes, which are cut out of sheet and made up on a mandrel, should be made from sheet doubled on the calenders; this is placed round the mandrel and cut from end to end of the latter

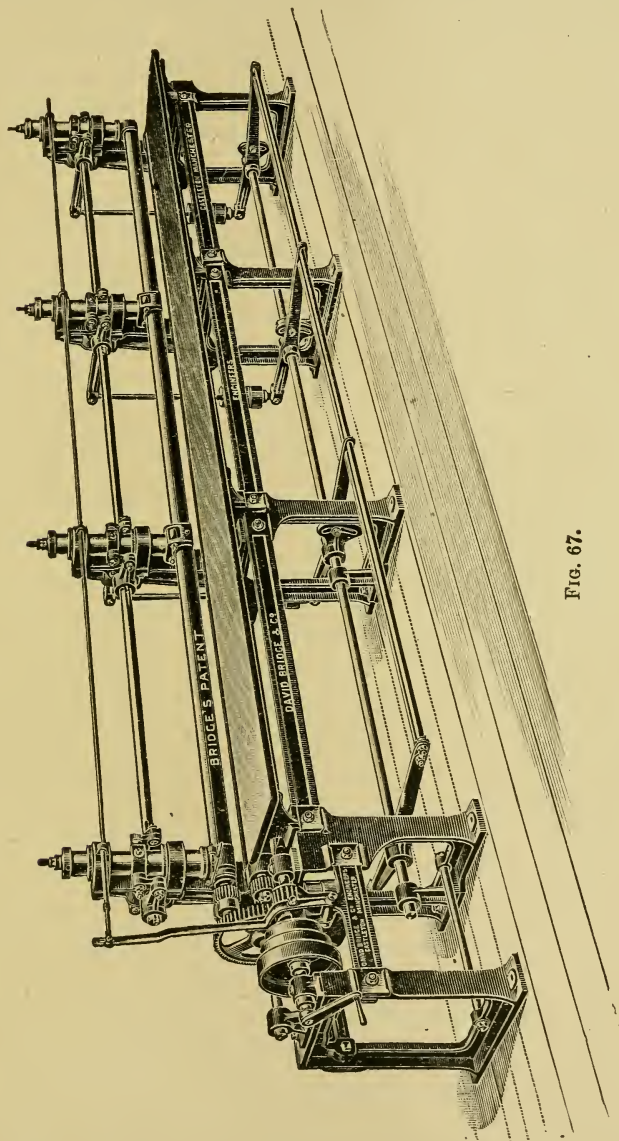


Fig. 67.

by means of a special cutting machine, the cut edges being at the same time pressed together so as to form an absolutely tight seam. The inner tubes are wrapped, just as they are made up, on the wrapping-machine (fig. 67), and are then vulcanised at 135° C. The

tubes are drawn off the mandrels with the aid of compressed air, being at the same time turned; holes are made for the valves, and the tubes are then cut to the right length, the ends solutioned with a pure Para solution, moistened with chloride of sulphur solution, and united. Motor tubes are often moulded, in which case the necessary amount of gas-producing materials is put inside the tube; a mixture of bicarbonate of soda and tartaric acid in tabloid form being the most convenient agent to employ.

The manufacture of pneumatic tyre outer-covers, on the other hand, necessitates the use of considerable mechanical arrangements; in particular, a large number of moulds which are best made of cast steel. Of these there are two kinds to be considered—drum moulds and core moulds, which latter are used especially for motor tyres. The manufacture of drum-cured covers is in principle as follows:—Cotton fabric, proofed on the calenders, is cut on the bias, and two layers are then rolled down on to the drum. The first layer of fabric carries the rubber cover known as the tread, which lies on the side next the mould. The strip is rolled into the cavity which forms the beaded edge, this being filled up with a cord of a hard-rubber mixing, and the second layer of fabric is then put on. The drum is now wrapped round with a cotton cloth on the machine depicted in fig. 68, and then with wire, and is run into the heater on a large trolley. It should be noted that vulcanisation should not set in before the layer of rubber has had time to spread itself evenly over the surface of the mould, otherwise markings similar to air-markings will result. These are not, however, to be attributed to the shrinking of the rubber, but rather to the fact that when it was rolled on to the drum the layer of rubber was not evenly spread out, and that this could not be remedied once vulcanisation, which proceeds energetically even at 130° C., had set in. For this reason, in the case of drum-cured covers, care should be taken to heat up the moulds slowly, after which the vulcanisation may be carried through more rapidly. Tyre covers which used to be made of pure Para, to-day consist of mixings similar to, or even of lower quality than, the following:—

Congo	10,000 gms.	Whiting	3,000 gms.
Pitch or asphalt	1,000 ,,	Sulphur	1,500 ,,
Reclaimed rubber	8,000 ,,	Dark substitute	10,000 ,,
Litharge	750 ,,		

The manufacture of motor-tyres was built up on the principle of the pneumatic core-tyre, and in course of time has developed into its present degree of perfection.

The principal conditions to be observed are, first and foremost, to see that the fabric to be employed is carefully proofed. The rubber should not be liable to after-vulcanisation, nor become tacky, and must be able to withstand the heat and vibration brought about by friction and blows. The covers are made up on solid iron cores made in several pieces, and consist of the layers of fabric—the details of which are determined by the shape and

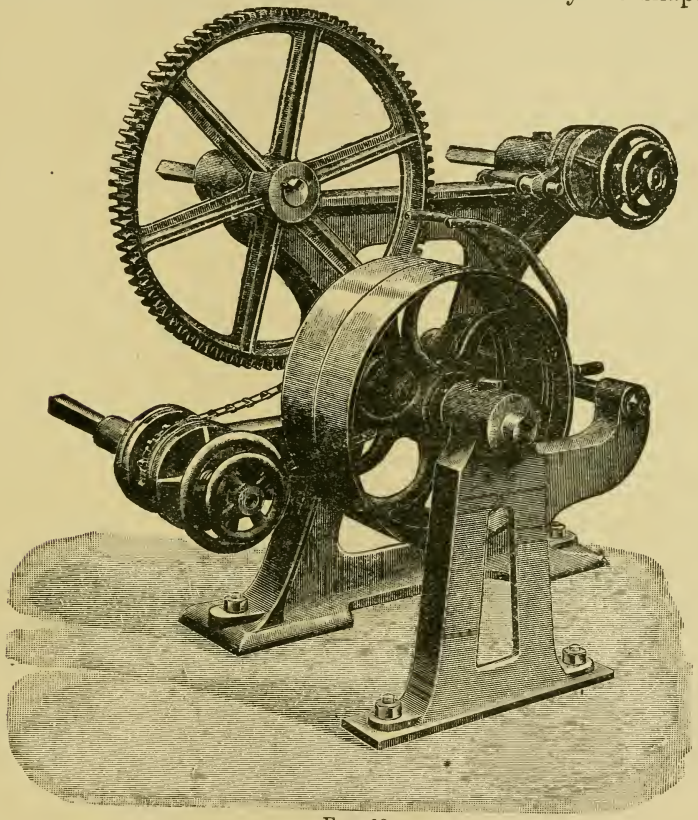


Fig. 68.

size of the tyre, and between which there should be neither dust nor air-holes—of the attached beaded edge and of the cover (tread). The latter is either built up from single strips, or the complete section is run out on Tröster's special tyre calenders. The compressing and vulcanisation are carried out either in the closed nest of moulds (fig. 69, A and B) or, better still, in hydraulic autoclave presses.

Moulds vulcanised in the above-named autoclave are subjected to a continuous pressure, which increases with the opposing pres-

sure of the tyre inside the mould, and so ensures that the separate layers are vulcanised together into a solid mass free from air-holes.

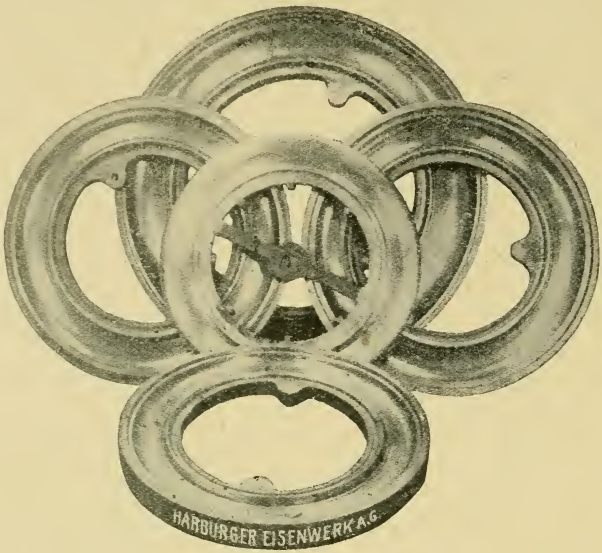


Fig. 69, A.

At the same time the moulds are entirely surrounded by the steam necessary to effect vulcanisation,[1] at a uniform temperature.

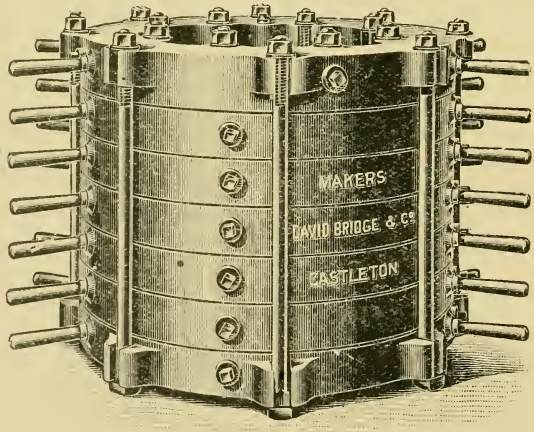


Fig. 69, B.

Pedal- and brake-rubbers are for the most part run on the tube machine in the form of shaped strips, corresponding with the die used, vulcanised in French chalk, and subsequently cut to the

[1] See also the article "Kombinierte hydraulische Kesselpresse" in the *Gummi-Zeitung*, 1905, vol. xix. p. 1001.

proper size by means of an eccentric punch, holes being at the same time punched in them. The matrix which holds the knife and the punch can be adjusted to take all sizes. One man can punch on an average 8000 flat pedals in a day. Curved brake-rubbers with a hard-rubber inner layer are run on the machine in the two different qualities, joined together by means of solution, cut up into pieces of the proper size, and vulcanised in French chalk. The curved surface is buffed into shape on the lathe by means of a shaped emery-wheel. Complicated rubbers must be made up and vulcanised in moulds.

Solid bicycle-tyres are run on the tube machine and then vulcanised in moulds (fig. 70) under the hydraulic vulcanising press, endless tyres being made in suitable closed moulds, as also are cushion tyres.

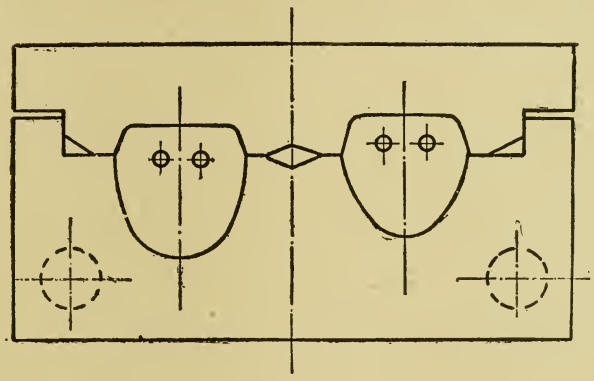


Fig. 70.

Perambulator tyres are also machined, and are then joined up and vulcanised in chalk in the open, or in moulds under the press.

9. **Manufacture of Soft-Rubber Surgical Goods, etc.**—The manufacture of air-cushions, water-cushions, mattresses, hot-water bottles, and also of gas-bags, constitutes another department of the industry, to which it is now proposed to direct the reader's attention.

The three chief factors for success in this branch are: (1) clean, dense mixings, free from grit; (2) calendered sheet of uniform thickness, and fabric closely proofed; (3) careful hand labour.

The mixings in most frequent use are white ones.

For cushions, *e.g.*, the following mixings may be recommended:—

Mozambique . .	10,000 gms.	China-clay . . .	3,500 gms.
Sulphur . . .	1,200 ,,	Ceresin	200 ,,
Zinc white . . .	6,500 ,,	Magnesia usta . . .	200 ,,

The mixing is in part run into lengths of doubled sheet on the calenders, and made up into cushions with cloth-impression; and in

part made into smooth sheet to be used for smooth-surfaced cushions and other articles; for this purpose short lengths of sheet are run on the calenders, and after being cut up are pressed smooth between zinc plates under the press. If sheets with a cloth-impression (twill-impression, etc.) are selected, the calendered sheet is rolled up at once in the damp cloth and allowed to remain under pressure over-night. Sheet of this kind has the advantage that its surface is free from chalk, which is not the case with the sheet pressed between zinc plates. The sheet to be worked up is slightly warmed, so as to shrink it, then cut out with the corresponding templates, the two layers being cut out with one cut. The edges of the two layers are carefully separated from one another and a little chalk introduced between the layers to prevent them from sticking together. The seams are moistened with solution, and when dry are pressed together. All surgical goods of soft rubber are generally made up in this manner if they are to be vulcanised in the open without moulds. Such goods are evenly embedded in French chalk, so as to leave no air anywhere between the two, which would result in the surface being marked. The goods are firmly covered with chalk, then the trays are covered over and run into the heater, and vulcanisation is at once started with a rapid rise, and carried through.

Enamelling.—Hollow articles, such as balls and syringes, which are cured in moulds in the usual way, are coated with red, green, white, and black enamels in the following manner:—The enamel mixing, which may have one or other of the under-mentioned compositions, is dissolved in benzine, filtered through the press illustrated in fig. 71 (of which 71A represents a form worked by hydraulic power), and then poured into a rectangular containing-vessel, care being taken to avoid the formation of blisters.

	Red.	Yellowish-red.	Green.	Black.	White.
Para	750	750	750	1000	1000
Golden sulphide, yellow	...	800	...	...	...
Ochre, yellow	...	200	...	...	...
Carbon black	...	...	...	300	...
Snow-white	...	...	...	...	800
Chrome green	...	...	550	...	...
Vermilion	300	100	...	...	...
Golden sulphide, carmine	600	...	...	...	...

The articles to be enamelled are dipped into the solution on pegs fixed in wooden laths, withdrawn, and allowed to drain, and

then put to dry on a face-plate which is kept in eccentric motion so as to enable the solution, while still thin, to distribute itself evenly over the surface. When the enamel has dried off, the last traces of solvent are removed by drying in a dust-proof room,

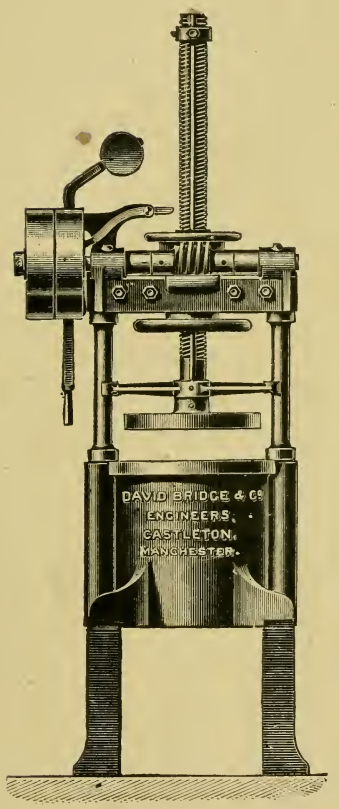


Fig. 71.

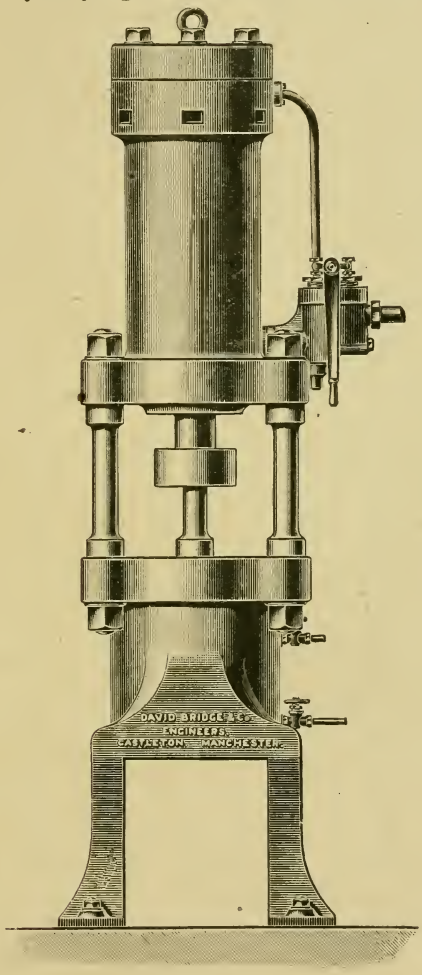


Fig 71A.

heated with hot air, and the goods are then vulcanised by means of a dilute solution of chloride of sulphur (1:600), and dried off again. Finally, they are polished with a carefully filtered solution of shellac, a fine brush being used for the purpose. Care should be taken that the solution does not skin over and that quite a thin coating is put on, otherwise it will flake off and crease.

10. **Bands and Rings.**—These small articles form, like eraser rubber, important articles of commerce. The manufacture of them is not at all difficult, but it is essential that the goods should not become brittle should they remain unused for a considerable time.

Most red bands, in their various sizes, have to stand considerable stretching, and this must be borne in mind from the very beginning of the manufacture. In no case should the mixing be overworked, but should be run into sheet as rapidly as possible. Suitable compositions are as follows:—

A.	Para	10,000	gms.
	Golden sulphide	2,500	,,
	Vermilion	500	,,
B.	Para	7,500	,,
	Kassai	2,500	,,
	Golden sulphide	2,500	,,
	Vermilion	500	gms.
	Brown substitute	3,500	,,
C.	Lopori	10,000	,,
	Golden sulphide	3,000	,,
	Barytes	4,000	,,

It is not advisable to run the sheet round and round the calender roll until it is smooth, but it should be run on the three-roll calenders, and doubled, as already described, from 0·5 mm. sheet, and finally rolled up tightly on the roller and allowed a whole day to cool down. This method has the advantage of giving a much tougher sheet, and any small air-blisters that may have been present will have been got rid of by bursting. When the sheet has been unrolled the separate pieces are gently warmed and pressed between zinc plates. The polished sheets are put through a cutting machine which cuts them into bands of a definite width, lays the ends together to form a tube, and at the same time presses the seams together. In order to make the seam quite secure this tube now passes under two mallets, working one behind the other, which hammer the seam. The tubes are vulcanised on glass mandrels, on which they fit tightly, and the heat is applied by means of a water-bath preferably to laying the goods in chalk, the temperature being raised rapidly and the cure completed at a pretty high temperature. The coupon bands and rings are cut from the tubes on automatic lathes.

Series rings are made up like tubing on mandrels. It is best to use thin sheet for this purpose; the tube is wrapped and vulcanised as such, and from it the rings, 0·3 mm. in width, are afterwards cut on an automatic lathe.

If tinned steel tubing be used for the mandrels, a smooth glossy appearance is imparted to the inside of the ring, and no French chalk need be used on the mandrel. The rubber used for these rings contains a very low percentage of sulphur, and the rings have

therefore little tendency to bloom; it is therefore hardly necessary to boil them up after curing; they are, however, cleaned with soap and water, and then, in order to give them a polish, rubbed over with a very weak solution of glycerine to which a few drops of oil of roses have been added in order to mask the smell of the rubber.

If the rings become tender, this is probably due, assuming that vulcanisation has been properly carried out, to excessive working of the rubber on the mixing- and calender-rolls.

11. **Rubber Stamps.**—The manufacture of rubber stamps may be subdivided into the following series of operations:—

1. The preparation of the matrix.
2. Pressing the matrix in contact with unvulcanised sheet rubber.
3. Vulcanisation.
4. Mounting up the finished stamp.

The second and third of these operations are the most important parts of the manufacture. The type is first of all composed as in ordinary printing, and the composition is then tightly closed and a proof is pulled to see if it is correct. The composition is then levelled so that the tops of the letters are all in the same plane, after which it is transferred to the chase, closed up tightly together, so that none of the letters can get displaced, and the matrix, in which the letters are to appear sunk, is now prepared for casting. Formerly the surface of the type used to be painted over with oil or graphite, and plaster poured over it, care being taken that the whole of the type was evenly covered with plaster, and that all the intricacies were filled up. The surface of the plaster was kept smooth as long as it could be worked, and was then allowed to set, after which the plaster matrix, which had taken the impression of all the hollows, was lifted out and dried off. It was then given a thin coating of shellac, in order to produce a smooth surface and to impart greater durability, and a positive impression could now be taken on the sheet of rubber. The surface of the matrix was dusted over with chalk; a piece of unvulcanised stamp-rubber of suitable size, also chalked, was laid on the matrix and vulcanised under the press. The rubber sheet, while still soft, found its way into every depression in the matrix, then became vulcanised, and when the press was raised a reproduction of the original type was obtained. Finally, each separate rubber stamp was cut out and mounted on a suitable support.

This old and complicated process, which did not always give

sharp impressions, has had to give way recently to a simpler and more rapid method of stamp manufacture. In this method the type is prepared and set up in the same way as described above. A negative plate is then made in a moulding-box, with matrix material stirred up with glue-water to a thick paste, by pouring the mass into the moulding-box, spreading it evenly, working it with a spatula until it is free from air-bubbles and lumps, and then carefully levelling the surface. The surface of the matrix-plate should be as smooth as glass, and should feel waxy to the touch. The type is now covered with a strip of rubber or fabric, firmly clipped in a mould press, and the matrix plate pressed tightly on it. An impression of the type in the sunk form is thus produced, but it is not yet deep enough nor sufficiently sharp. The strip is removed, the type moistened with benzine, thin pressing-strips of tinfoil or paper inserted, and the type repeatedly pressed into the matrix in order to deepen the impression. From three to five such pressings are enough to produce sharp, accurate impressions of the type in the matrix. The matrix is trimmed with a sharp, flexible knife, and carefully dried in an oven. This renders it as hard as stone, and suitable for taking impressions from in the actual unvulcanised stamp rubber. Thin strips of rubber are laid over the matrix so as completely to cover the impressions, and the two are now pressed together in the autoclave press. The rubber sharply and accurately fills up all the crevices in the matrix, and is fixed by vulcanisation, so that when the cure is complete the type is reproduced in rubber in sharp uniform outlines. The separate pieces of rubber type are finally cut off with scissors, and fixed in some suitable manner on the stamp handle. Vulcanisation is regulated according to the thickness of the sheets and the mixing employed, and is complete in, for example, fifteen to twenty minutes at 160° C. Another method which has been introduced in America may also be described. Instead of working with a matrix-mass, which has its drawbacks, and cannot be used more than once, the casting is poured with type-metal, and a metal matrix is thus obtained; this is very durable, and can be melted down after it is done with, and the metal used over again for other castings. From this metal-matrix the rubber stamp is prepared direct in the way already described. By the use of machines for composing, casting, and printing, large quantities of stamps can be automatically produced; such stamps turn out very accurate. In addition to letterpress, designs of all kinds can be equally well produced in rubber stamps, and up to considerable sizes. The finished rubber stamps are cut into circular, oval, or

angular shapes, and are fastened on to the handles with pure Para solution, lightly vulcanised with a very weak solution of chloride of sulphur before the two parts are stuck together. Since with fixed rubber stamps it is only possible to print the actual letter-press or the design of the one particular stamp, attempts have been made to improve upon them by introducing movable ones, by the aid of which one is able to make a number of different impressions with the same apparatus. Rubber bands on which the type is fixed work over rollers enclosed in a case; by the rotation of these bands a series of different arrangements of the type can be obtained to print from. The most practical form of rubber stamp to manufacture is the wheel stamp, in which the individual symbols or letters are carried on the teeth of the wheel, and which are very rapidly vulcanised in steel matrices in which the various teeth and symbols are engraved.

In order to get an accurate stamp impression on vulcanisation, the unvulcanised rubber on exposure to heat should first become sufficiently soft, and then cure rapidly without becoming stiff and inelastic in the process. Further, the mixing should not contain too large quantities of substitute, which have a tendency to cause the rubber to stick to the mould, and care must be taken to avoid porosity, to which revolving rubber stamps are especially liable, on account of the thickness of the rubber used.

The following mixing may be recommended for revolving stamps:—

Kassai or Mozambique.	10,000 gms.	Litharge (free from peroxide) . . .	14,000 gms.
Substitute (brown, rape oil)	8,500 ,,	Whiting . . .	5,000 ,,
Magnesia usta (heavy).	2,200 ,,	Zinc white . . .	10,000 ,,
		Sulphur . . .	4,000 ,,

and for ordinary stamps one may use:—

Para	10,000 gms.	Sulphur . . .	3,000 gms.
Substitute (brown, rape oil)	1,000 ,,	Zinc white . . .	7,500 ,,
Magnesia usta (heavy)	2,000 ,,	Litharge (free from peroxide) . . .	2,000 ,,

Cheaper quality:—

Para	5,000 gms.	Litharge (free from peroxide) . . .	3,000 gms.
Columbian . . .	5,000 ,,	Zinc white . . .	8,000 ,,
Talite or atmoid . .	2,000 ,,	Vaseline . . .	500 ,,
Magnesia usta (heavy) .	2,000 ,,		
Sulphur . . .	3,500 ,,		

Only glycerine inks are suitable for use with rubber stamps; a blue ink is composed of the following ingredients:—100 gm. distilled water; 100 gm. wood vinegar; 100 gm. methyl alcohol; 700 gm. glycerine; 30 gm. methylene blue, pure, free from dextrin and starch.

The methylene blue is dissolved first, and the glycerine then added, the solution being filtered if necessary. If the methylene blue used is pure there should be no insoluble residue. From the point of view of durability of the stamp, inks free from acetic acid are preferable.[1]

12. **Waterproof Cloth.**—The manufacture of waterproof fabrics is one of the oldest branches of the rubber industry. The proofed fabric may either be used as it is, without being further dealt with, for a variety of purposes, or it may be used, in the making up of other rubber goods, in the form of insertions or as an outside covering to them. Attention was directed towards the coating and impregnating of fabrics with rubber shortly after the appearance of raw rubber in Europe, on account of the imperviousness of such fabrics to water, and, after the discovery of methods of vulcanisation, waterproof cloth became an article of very considerable importance. But with the lapse of time, methods of proofing have been subject to fundamental changes. In the early days the rubber solution was applied to the cloth by means of a brush, this painting process being repeated until the coating of rubber was thick enough. Oil of turpentine was at first the solvent employed, and this was later on used in admixture with a somewhat crude coal-tar oil; later still petroleum came into use, and finally benzine and benzol. Not only was such a method accompanied by great loss of solvent, but it was an extremely defective one from the point of view of the unevenness of the resulting coating, due to the employment of hand labour. This unevenness was brought about by the circumstance that in scarcely any solvent is rubber completely soluble; as a general rule a quantity of incompletely dissolved, swollen particles remain in the solution, and show up very prominently as streaks, spots, and lumps in the rubber. This method of proofing has, however, been discarded, as machines have been perfected which do the same thing more efficiently.

When necessary the nap of the fabric is removed by means of a specially constructed singeing machine.

Spreading-machines (fig. 72) have long been in use for the production of proofed cloths for technical purposes, or for use in the factory itself, and to-day most of the proofed material turned out is produced on similar machines, though these have already been superseded to some extent by the spreading-calenders (fig. 73).

[1] See also "Die Herstellung von Kautschuk-stempeln," *Gummi-Zeit.*, 1906, xx. p. 1000.

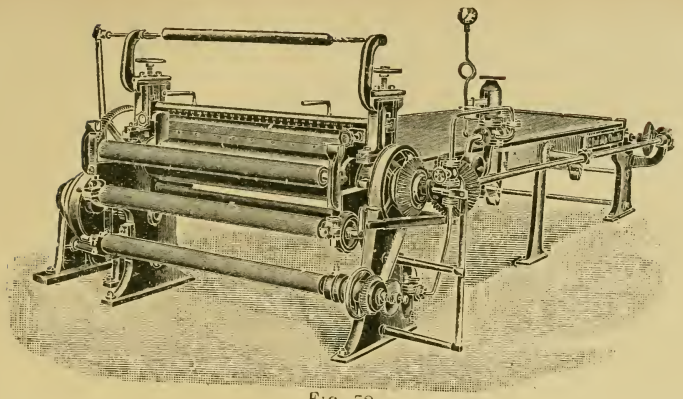


FIG. 72.

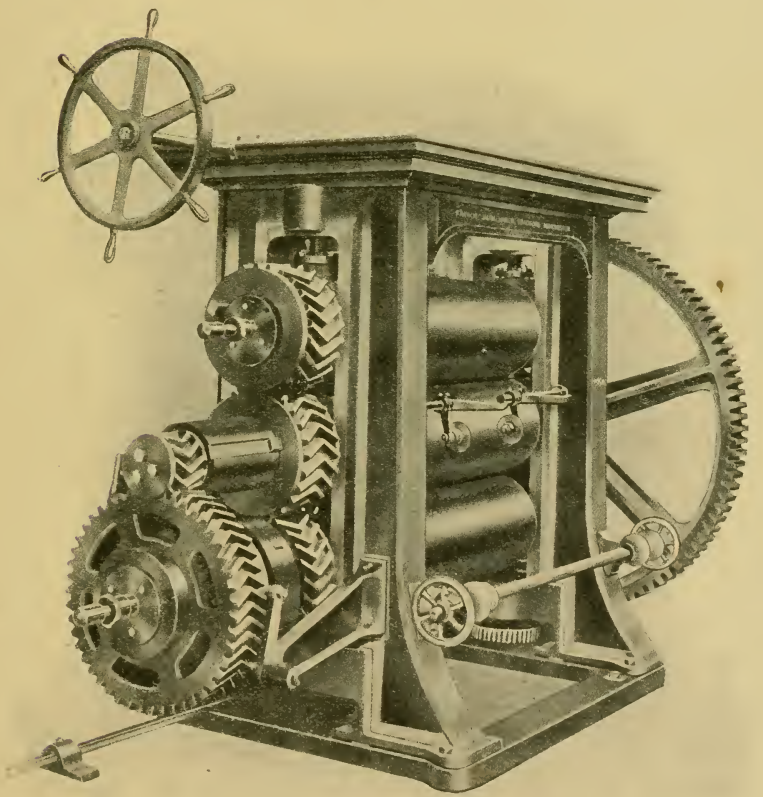


FIG. 73.

The general design of the spreading-machine is clearly shown in the illustration, and only those special points about it need, therefore, be referred to which require the most careful attention in order that perfect goods may be turned out. In the first place, it should be remembered that different mixings behave very differently on the spreading-machine, and bearing in mind what a multiplicity of such mixings exists, the need for great experience in the management of a spreading-shop will be admitted without hesitation. Difficulties are not at an end, however, when the variety of the mixings has been dealt with; the fabrics used also differ very widely in the raw material of which they are made, in thickness of thread, and in the readiness with which they take up the rubber dough. In order to realise the great differences that exist, it is only necessary to compare a web material with a belting cloth, and, on the other hand, a Para mixing with a mixing such as is used for ordinary Tuck's packing. Mixings to be spread must first of all be worked up with a suitable solvent. Petroleum benzine is the one most frequently used, on account of the comparatively slight smell attached to it; solvent benzol is used less frequently, because the persistent odour which clings to articles in the preparation of which it has been used is often an objection. In works where the evaporated solvent is not recovered, the injurious effect of the benzol vapours, which cannot be altogether prevented, is against its use as a solvent. In most cases, also, when everything is taken into account, there is a marked difference of price in favour of benzine. The first and most important requirement for good spreading consists in the addition of the right quantity of benzine to the rubber. The actual proportions used are regulated by the kind of raw rubber employed in the mixing, and by the percentage of rubber present, as well as by the kind of fabric used. First of all, the proportion of 1 part of benzine to 1 part of rubber may be taken as a general guiding rule, the proportion of benzine increasing with the quality of the rubber and decreasing as the quality of the mixing becomes lower. A larger proportion of benzine should also be added when a coarse fabric is to be spread, so that the dough may be able easily to penetrate into the meshes. The highest proportion of solvent is, however, necessary when proofing very thin hat-cloths.

The fabric with its coating of rubber dough, after leaving the adjustable spreading-knife fixed over the spreading-roller, passes over a heating-table, where the solvent is evaporated. The steam-heated sheet-iron table is generally about 4 metres long by 1·6

metres wide. Even if the solvent used boils practically between the same limits, the rate of evaporation varies with the raw rubber used, and is greater in the case of mixings containing little rubber than in the case of those which contain more. Solvent left in the rubber is detrimental to it, and if it is not completely removed before vulcanisation is effected, the durability of the proofing is considerably lessened. The spread fabric should therefore pass so slowly over the heating-table that the last traces of solvent are driven off. The actual speed will vary according to the kind of proofing being dealt with; hence every machine is arranged to work at three, sometimes at four, different speeds. Petroleum benzine is preferable to solvent benzol also in this matter of evaporation from the proofing, since benzol often contains an appreciable quantity of constituents boiling above 130° C. which can only be removed by unduly prolonged heating. Petroleum benzine should, however, also be tested by fractional distillation, and if it contain an appreciable amount of constituents boiling above 130° C. it should be rejected as unsuitable. It is by no means necessary that the benzine should consist chiefly of constituents boiling below 100° C.; on the contrary, a solvent boiling between 90° and 130° C. is a much better solvent. But the benzine should contain nothing boiling above 130° C., because its evaporation would then be too slow, whereas a solvent boiling between 90° and 130° C. evaporates quite rapidly enough. It is well known that temperatures considerably below the boiling-point suffice to bring about the complete evaporation of benzines.

With a view to rapidity of working, the evaporation is often forced. Such a method of procedure is to be entirely condemned, for whenever rapid evaporation is resorted to blisters are formed, and defective places in the article result from the loosening of the rubber coating from the cloth. These blisters are productive of the greatest injury in the case of the so-called balloon silk fabrics, because this material has to withstand a high internal gas-pressure.

This defect also assumes far-reaching importance if the material is to be used as a waterproof fabric.

It should be seen, therefore, that the proofing is absolutely homogeneous, the number of coats varying, according to the nature of the material and the purpose for which it is to be used, up to as many as six, and each coat should be spread as thin as possible.

Not only can fabrics be spread in one colour, but in different colours, forming very beautiful patterns. This particular branch

of manufacture was very thoroughly worked out by the late John Minder, and the originality of his process justifies a careful description of it. The general idea is as follows. If a piece of stout paper be evenly folded together several times, and the corners then cut off with the scissors, together with a few triangular and curved pieces, a design is obtained, when the paper is unfolded,

Fig. 74.

somewhat similar to that shown in fig. 74. A piece of cotton fabric, as generally used for bed-sheeting, is now spread with white dough until an even coating is obtained. Then when the next coat is put on, the perforated paper is put between the roller and the fabric (see fig. 75). The rubber-covered roller *a* of the spreading-machine carries the paper *c* through smoothly, and the perforations

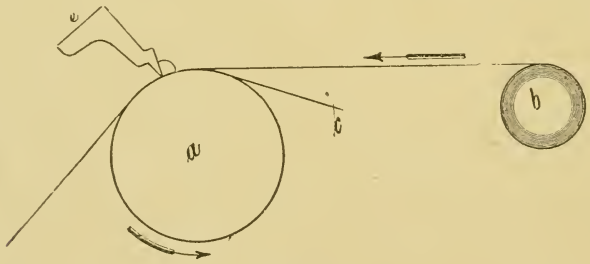


Fig. 75.

of the paper are shown in relief in the corresponding positions on the proofed cloth. The thicker the paper and the stiffer the consistency of the dough, the higher will be the relief of the pattern. If a coloured dough—*e.g.*, a pink rubber dough—be used for the last coat instead of a white one, the perforated portions of the paper will be represented by pink patterns on a white ground, but only if the following conditions are observed:—The spreading-knife must rest firmly on the partly-proofed material so as actually

to press into the rubber roller a little. The spreading-machine should then be run very slowly. By working in this way what happens is that the coat of white rubber in front of the knife has time to get softened, and that then the knife scrapes off a very thin layer of white rubber instead of spreading on a coat of pink, except in the places over the perforations of the sheet of paper, where the spreading-knife exerts no pressure; in these places a coat of pink rubber is left on, and the design so produced appears in slight relief. The pieces of paper which were originally cut out of the sheet are now taken and stuck on to the same sheet of paper in suitable positions, and the sheet so prepared is used in the same way as before. The design now obtained is the same pink on white arrangement as before, only in those places where the extra thickness of paper has come a counter-sunk appearance will be observed; this is, of course, produced by the additional pressure of the knife brought about by the extra thickness of paper. The sheet of paper can now be employed in another way. Another piece of material is put on the spreader, and spread with yellow dough, about three coats being put on. On the yellow a white layer is spread until a smooth coating, completely hiding the yellow, is obtained. Pink dough is now put before the spreading-knife, when on passing the material through, with the paper between it and the roller, a design in three colours is obtained. The places corresponding to the perforations appear in pink; from the places over the double thicknesses of paper the increased pressure of the knife causes the white coating to be completely removed, showing a pattern in yellow, and the groundwork of the whole remains white. It will now be clear that in this manner, by putting on several layers of rubber of different colours, and by building up or lessening the thickness of the paper in varying degrees, patterns can be produced on waterproof cloth in different colours and shades of colour, which have a very fine appearance and a characteristic effect. When it comes to proofing a piece of material with a continuous pattern, the simplest way would be to imprint the design on the rubber-covered roller. Such a roller would, however, be very difficult, if not impossible, to make, for it would have to be done with extreme accuracy, as an error of $\frac{1}{10}$ mm. in printing the material, if one may so describe the process, would result in faulty places. This can be got over, however, in the following way:—A piece of cloth of a certain length is coated to a thickness of 2 mm. with a rubber dough, not too soft. The design is then impressed continuously in the rubber coating, and the material

is vulcanised by heat. Fig. 76 shows the arrangement of the spreading-machine for producing the coloured design on the proofed material. *b* is the wooden roller carrying the material

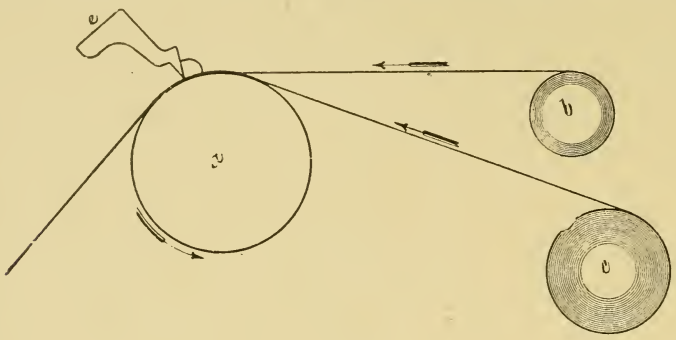


Fig. 76.

which has been already spread with the different-coloured layers of rubber. *c* is a similar roller carrying the material on which the design in relief has been impressed. In "printing," the two cloths run, one over the other, between the roller *a* and the spreading-knife *e*, the cloth which is to be printed in colour being above that which carries the design in relief. After passing over the heating-table each cloth is rolled up on a separate roller under the machine, in the usual way. The "printed" cloth exhibits fine effective designs in a kind of relief. The raised parts of the under-cloth are subject to greater pressure than the hollows, and the intermediate steps are gradual. The copy reproduces all the gradation of the original design, and stands out in the plastic state from the ground-work.

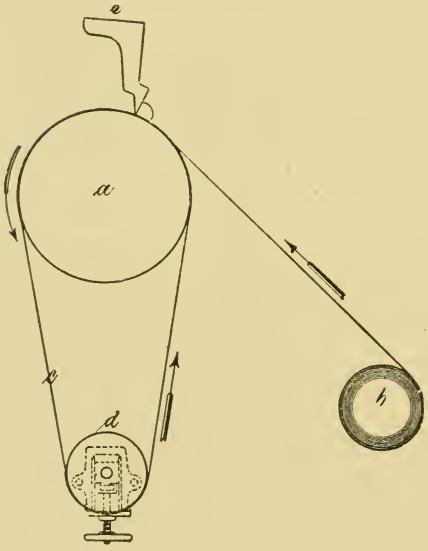


Fig. 77.

There is yet a third method of covering the proofing with a pattern. Figs. 77 and 77A illustrate the arrangement. *a* is the rubber roller of the spreading-maching, *b* the roll of material to be printed, *d* a wooden roller with its iron axle resting in bearings,

which can be raised or lowered by means of screws. Round the wooden roller *d* and roller *a* runs a cloth *c*, on which is the impressed design, in the form of an endless band. The ends of the cloth must be joined together very neatly, otherwise, on printing, a stripe will be produced in that particular place every time it passes under the spreading-knife. Further, the joint should be made in such a way that it can be easily undone, and the cloth removed readily from the machine after use. In this method the piece of proofed cloth is also printed continuously, but only a comparatively short piece of printing-cloth is necessary. The rubber roller carries the printing-roll—*i.e.* material *c*—continuously through under the

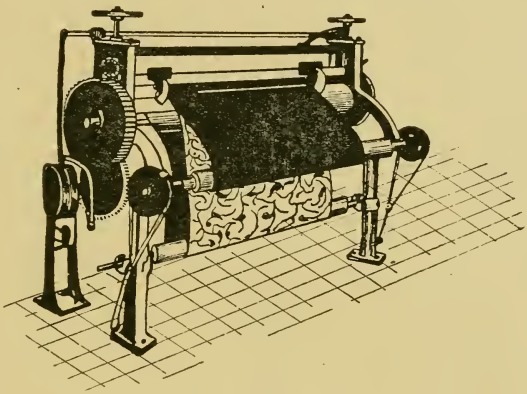


Fig. 77a.

knife. This cloth is always kept taut by means of the adjusting screws on roller *d*.

In order to get good results on the spreading-machine with patterned cloths it is most important that the roller should be buffed absolutely true. In the case of patterns consisting of simple figures, such as stars, dots, flowers, etc., a comparatively cheap printing-cloth can be made by punching the individual figures out of a stiff proofed material. When the design is a continuous one, however, it will have to be impressed in the way already described.

One does not yet very often meet with spreading-machines which are fitted with apparatus for recovery of the solvent, though such machines are made in Germany. Their construction was first described by Minder.[1] In this arrangement heating-coils take the place of the usual steam-chest, and these are contained in a long shallow chamber with a false bottom which is kept cool. The cloth passes through between the steam pipes.

[1] *Gummi-Zeit.*, 1898, viii. No. 7.

Only such colours should be used for the production of these coloured patterns as are not affected by the vulcanising liquor. The proofed cloths are treated in exactly the same way as others, being powdered with French chalk, flour, or potato starch on the special chalking-machine (fig. 78) in order to take away the tackiness from the surface, and then vulcanised by means of the cold cure.

Spreading-machines are now being partly displaced by calenders. The special advantage of the latter over the former is that when they are used no solvent is needed, and the loss occasioned by the

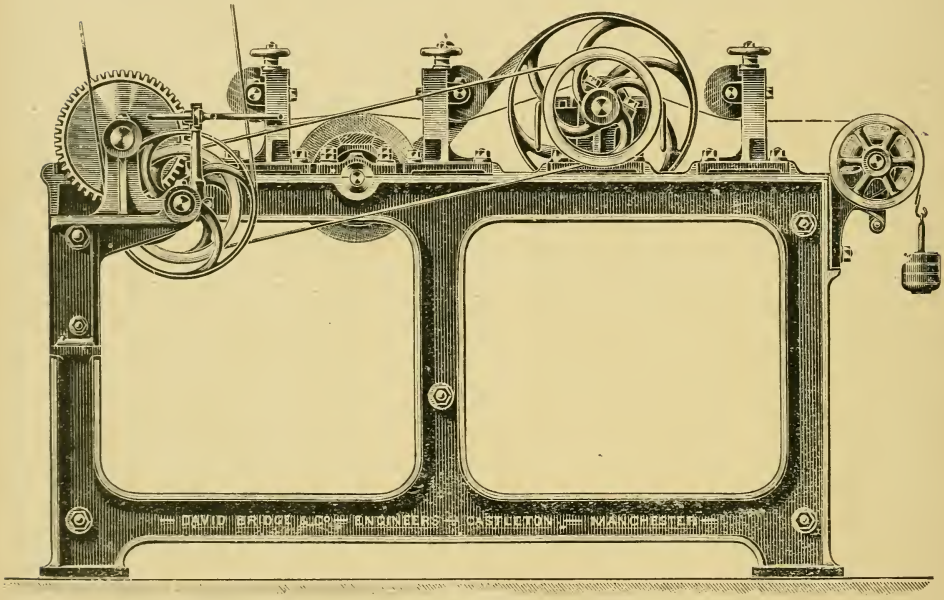


Fig. 78.

evaporation of such solvent is therefore entirely avoided. But in addition, and especially in the case of proofed material of medium thickness, the work turned out is far more uniform than is the case with spread material, and the work can be done very much quicker with the calenders, since no time is taken up by the drying process. The spreading-calenders are, however, not to be preferred to the other type of machine unless the rolls are most fully suited to one another, as regards both their circumference and their hardness, and unless the motion of the rolls is perfectly even and capable of being accurately regulated. Only solidly-built machines should be used for this purpose, and they should be driven by an electric motor, so that they can be run continuously at a uniform speed. The greatest

difficulties are encountered in spreading very thin coats of rubber, for the fabric is apt to get caught up and torn, the rolls being of necessity very close together. But in any case, with well-trained hands, the spreading-calenders can be used for most kinds of materials, and in America this is almost exclusively the practice; moreover, much lower qualities can be used for spreading on the calenders, qualities which could not be used at all in the form of solution at the same price.

After being spread or calendered the cloth has still to be vulcanised. This part of the manufacture has already been fully dealt with.

13. **The Manufacture of Imitation Leather Cloth.**—In the following pages this manufacture, which quite comes within the province of rubber manufacture, will be described.

Formerly the fabric to be used as a basis—a good bleached diagonal cotton is the most suitable—was proofed on the spreading-machine, which has already been described in other sections, but these cloths can no longer be produced by this method at a sufficiently low price; besides, the quality of the cloth prepared in this way is not nearly as good, the cloth feeling considerably softer after vulcanisation than cloth spread on the calenders, and so largely losing its resemblance to leather cloth because of its lack of hardness. The "friction process," which is to be briefly described, is therefore decidedly to be preferred.

The cloth to be proofed must be dried, stretched, and glazed, in order to free it from knots. It is then spread on the calenders with an ordinary mixing as a foundation, weighing about 400 to 450 grams per square metre. On this the outer coat is frictioned, to a weight of about 150 to 200 grams per square metre, and the coated cloth, after the whole length has gone through the calenders, is passed through the embossing-machine (fig. 79), provided with engraved rolls which can be changed as desired. By this machine the pattern is impressed on the cloth. The embossing calenders are of similar construction to those used in paper manufacture, in which a bronze or steel roller, on which the design is engraved, is mounted between two large paper rollers which take up the pressure, generally produced by means of a weighted lever. This arrangement possesses the advantage that a comparatively small engraved roller can be used.

On passing through the calenders the engraving on the roller is sharply imprinted on the proofed cloth. Care must naturally be taken to see that the different qualities of mixing used have the necessary relative plasticity, and that the outer coat of rubber is

extremely firm and extensible, so that it is only very slightly weakened in the hollows. If there is not sufficient substance in the outer coat, it would easily be broken or torn at these places on bending or folding. On the other hand, the rubber should not be too hard, or the outer coat will be cut through by the engraved roller, while the use of too plastic a mass will lead to blurred impressions. After leaving the embossing-rolls the cloth passes

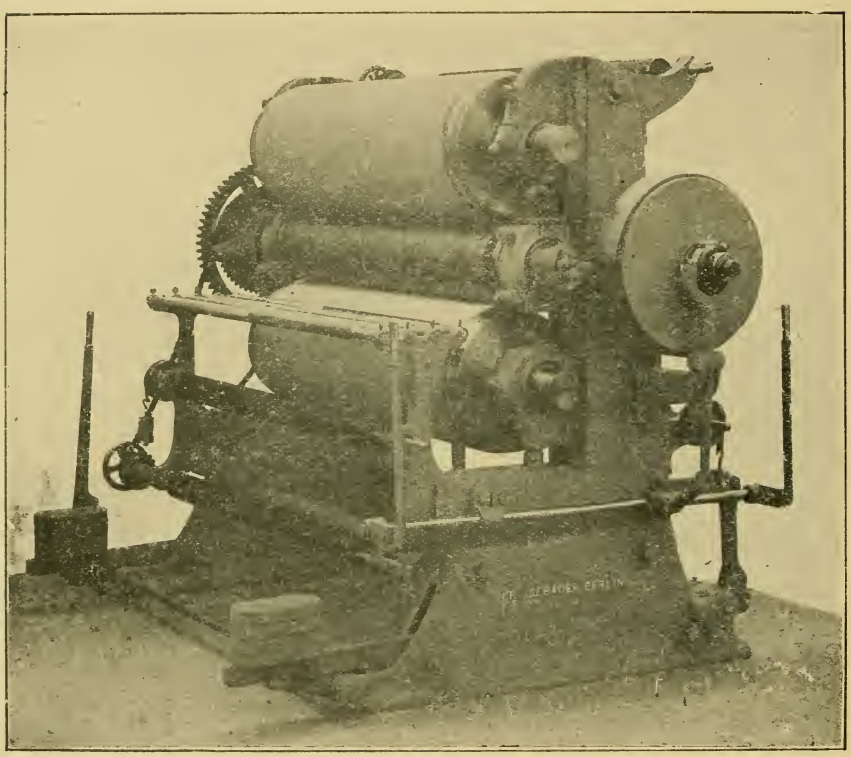


Fig. 79.

over the varnishing machine, where it is slightly moistened with the varnish, and from this direct to the vulcanising room, where it is hung up and vulcanised. These two processes go hand in hand, because the varnished cloth must be hung up immediately on leaving the machine, and cannot be rolled up while the varnish is still fresh. The best varnish is one mixed with linseed oil, varnish, and hard resin, this being harder than shoe varnish, and possessing better drying qualities, which prevent it from afterwards sticking together. The varnish should, when absolutely dry, give a highly polished appearance to the cloth.

The stove already described (fig. 40) is used for vulcanisation, which is effected by means of hot air. After vulcanisation the cloth is allowed to cool for twelve to fifteen hours, and is then hung up in the air, so as partly to rid it of the smell of rubber, and to do away with the tacky feel of the varnish.

14. **Manufacture of "Cut-Sheet."**—This product, invented by Charles Macintosh, is a very fine article of commerce, chiefly used in the manufacture of surgical goods. It has been produced in a variety of ways from time to time, and it seems desirable to put before the reader the different methods of manufacture from which the rational methods at present in use have been evolved. In the first place, pure Para rubber without any added sulphur or surrogates

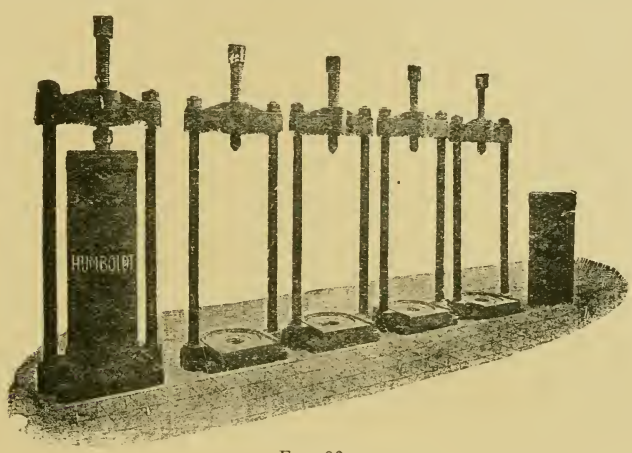


FIG. 80.

was worked up into a soft mass by mastication between hot rolls; this mass was forced into a cast-iron pot about 2 metres long and 35 cm. wide, and the process was repeated until the pot was filled, when it was submitted to a high pressure. By this means a large homogeneous block was obtained; this block was kept at the temperature of a cool cellar for as long a period as four months, whereby the original good mechanical properties of the rubber were restored to it. Sheet was afterwards cut from these blocks, by fixing them on a horizontal moving bed, which was then driven against a sharp knife making about 700 to 800 oscillations per minute, a copious flow of water being kept up over the knife. In this way sheet of different thicknesses was cut by altering the adjustment of the bed. The surface of cut-sheet is marked, as a result of this mode of cutting, with ripple-like knife-cuts. The finer these markings are in the finished sheet the more rapidly

has the block been pushed against the knife, or the faster has the machine been run. When a complete sheet had been cut off, the block was raised up on its supporting bed through a distance equal to the thickness of the next sheet to be cut.

This method has been replaced by that about to be described, because by its use it was only possible to prepare short lengths of sheet of medium width. The method now in use is as follows:—

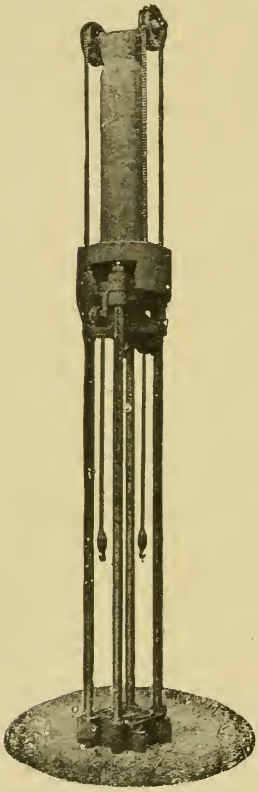


Fig. 81.

The sheets of washed rubber are worked in masticators into the form of solid masses; when these masses are quite homogeneous, and while they are still plastic, they are forced into vertical steel cylinders which have previously been heated (fig. 80). These cylinders are 120 cm. long and 35 cm. inside diameter, and have loose bottom-plates. The cylinders are stood under a cross-bar through which there passes a screw-spindle which is used to force down the cover of the cylinder on to the mass of rubber in it. A steel spindle runs centrally through the cylinder, and forms when withdrawn the hollow axis for the reception of the cutting spindle. But this method has again been improved upon by employing a cylinder of about 43 cm. in diameter, completely filling it with the masticated rubber, and only then forcing the steel spindle through the whole mass of rubber, the compactness of which is by this means increased (fig. 81). The pressure necessary to drive the spindle through is about 260,000 kilos. The moulds are then subjected to a gradually increasing pressure under the presses illustrated in fig. 80 until the whole has become quite cool and a block free from pores is produced. The cylinders containing the compressed rubber are no longer cooled down in a chamber by means of ice or cold air, on account of the large amount of expensive raw material which is kept lying idle during such a process, but they are immersed in a freezing-tank containing salt water cooled down to a temperature of $-5°$ C.

In fig. 82 is shown diagrammatically a modern freezing plant for "cut-sheet" blocks (Haubold's system); with the aid of this plant 320 kilos. of rubber can be completely frozen per diem.

In this diagram we see the compressor *a*, built in one piece with the condenser, the evaporation pipes *b* in the refrigerator (salt-water reservoir) *c*, in which the freezing mixture (brine) is cooled down till the temperature falls to $-12°$ C. in the evaporator. In general, the scale on which it is advisable to design the freezing plant is one which allows 30 to 35 square metres for the floor area and $2\frac{1}{2}$ metres for the height of the cooling and storage space, and provides for an artificial cooling capacity of 4000 calories at a salt-water temperature of $-12°$ C. A small pump *d* is coupled to the compressor in order to supply the cooling water necessary for the condenser. If a supply of main water is available for this purpose this pump is not necessary. The blocks are lifted in and out of the

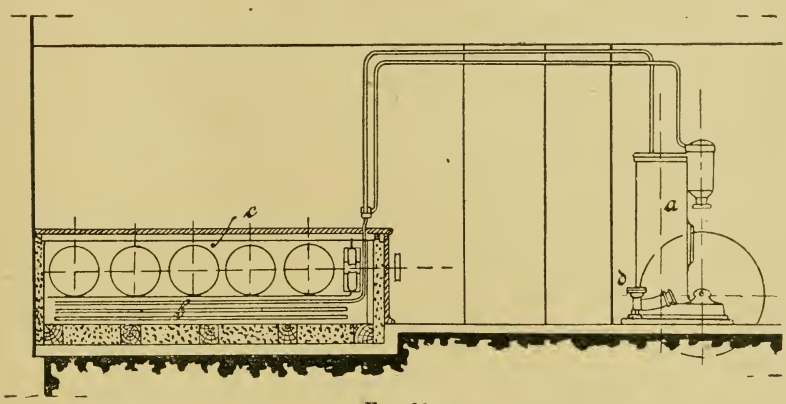


FIG. 82.

tank by means of lifting tackle; the steel spindle is forced out by hydraulic pressure, and the cutting spindle having been inserted in its place, the block is ready for cutting. The machine on which these blocks are cut differs essentially in design from the earlier form of machine; in fig. 83 a cutting machine of the latest construction is shown; in this machine the cone-drive is again used instead of the friction-drive, because the desired results were not achieved satisfactorily on all sides. The machine can also be used for double blocks.

The block is cut spirally by the knife of the machine into the form of a sheet, the speed of rotation of the block and the throw of the knife being regulated and adjusted according to the thickness of the sheet. The knife oscillates at the rate of up to 1200 times per minute; it is therefore most important to keep it well lubricated, and to see that the apparatus for keeping the knife and block wet with soap solution is in perfect working order. The knives are

sharpened on a special emery-wheel machine, and the production of a uniform sheet of rubber depends upon their having a true sharp cutting-edge. Soap solution is used in order to prevent the sheets

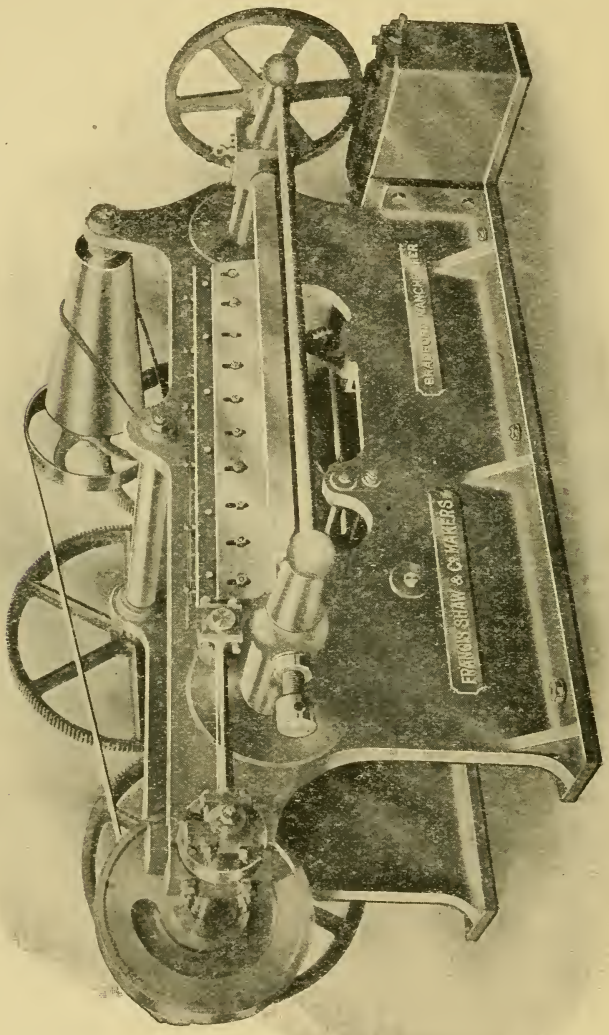


Fig. 83.

from sticking together when they are laid on one another while warm. The soap solution has no effect upon the later processes of manufacture. The various thicknesses of cut-sheet are distinguished by numbers as indicated in the following table:—

No.	mm.	No.	mm.	No.	mm.	No.	mm.
1	4·15	6	1·66	11	0·63	16	0·33
2	3·26	7	1·40	12	0·54	17	0·20
3	2·58	8	1·15	13	0·44	18	0·18
4	2·35	9	0·95	14	0·41	19	0·165
5	1·85	10	0·84	15	0·37	20	0·143

The quality of cut sheet (German, *Patentplatte*; Italian, *foglia segata*; French, *feuille anglaise*) has undergone considerable reduction. Sheet formerly made from pure Para has been gradually lowered in price, other mixtures of raw rubber being used instead of Para, and at present sheet containing as much as 30 per cent. of surrogate is sold. Red cut-sheet is prepared by the addition of vermilion to the rubber. Green sheet has disappeared again from the market.

The cost of working a cut-sheet plant is not very high.

It requires altogether six men for a monthly production of about 2500 kilos. of medium thickness. The consumption of ammonia or carbonic acid is quite insignificant, but lubrication must be reckoned at about 30 kilos. of oil per month. To cut a block weighing about 75 to 80 kilos. into No. 18 sheet takes about twenty hours; but, on the other hand, a similar block can be cut into No. 9 sheet in about five hours. Once the block is fixed in position on the machine and trimmed, it pays to keep the machine running continuously until the whole block is cut out, on account of the saving of time, on the one hand, and on the other hand, of the reduction of waste.

15. **Manufacture of Rubber Shoes.**—The manufacture of rubber shoes or galoshes forms a separate branch of rubber manufacture. Special methods are demanded in most of the operations connected with it, leaving the preparation of the raw rubber out of account. The reasons for this are as follows:—

1. The use to which galoshes are put differs greatly from that of other rubber goods, and puts great demands upon the strength and elasticity in every direction, especially in the seams, while at the same time elegance, a good finish, comfort and ease of manipulation are necessary qualities.

2. In the manufacture of galoshes, mixings of the most varied nature, from the finest to the lowest qualities, in all possible thicknesses of sheet, as well as in the form of sheet spread on fabrics of all kinds, the rubber layer varying both in quality and in thickness, have to be made up together from a comparatively large number of small separate parts, and this must be done in such a way that the finished article shall appear as if it came from a

mould; indeed the uninitiated often actually look upon the rubber shoe as a moulded article.

3. The making-up—that is to say, the manufacture proper of rubber shoes—can only be carried out by hand. The machines invented by the American, Doughty, have not come into use in spite of their ingenious design, the cost of working them being too high.

4. Such large quantities as 4000 to 12,000 pieces, according to the size of the factory, are vulcanised at a time, so that the greatest care must be given to mixing, labour, and organisation.

Before passing on to a description of the manufacturing processes, a few points of general importance may be discussed. Galoshes, like all other kinds of shoes, are made up on lasts; the size and shape of the last determines that of the shoe, and since rubber shoes are made in an extraordinary number of shapes and sizes, it is necessary in a galosh factory to have a considerable stock of lasts, in the first place of different sizes and shapes, and secondly, a sufficient number of pairs of each size and shape. The lasts are made either of wood, iron, or aluminium. Iron lasts possess the advantage of heating up rapidly in the vulcanising chamber, and of not being subject to appreciable wear or to fracture. On the other hand, their great weight adds considerably to the labour of making up the shoes, and of carrying them to and fro in the factory. The expansion of the metal by heat is also a disadvantage, because it always results in some distortion of the seams. Wooden lasts, though more subject to wear than metal ones, are lighter to handle, and do not undergo any appreciable expansion on heating, provided they have been well dried beforehand. To ensure that this is so, the wood, in the form of small blocks, is stored for a long time in a very warm place—directly over the boilers, with advantage—before it is shaped out; from this stock the oldest blocks are always taken for use first, blocks which have sometimes been drying for a year and which neither shrink nor crack, nor otherwise alter in the heat. Maple is the most suitable material to use.

Another point of general importance is the uniform colour of the whole shoe, and every mixing used should either be black in itself, or should become black during vulcanisation. These black mixings are prepared by the addition of carbon-black, as well as by the addition of pitch prepared on the factory by heating coal-tar. In this operation the tar is heated and kept continually stirred until it forms, on cooling, a tough mass; resin and wax are some-

times added while the heating is going on in order to impart a bright polish to the mixings in which the pitch is used. The resin-content should, however, be extremely limited, and if it is put in at all, should not exceed about 5 per cent., otherwise the mixings will easily crack. Thickened coal-tar pitch communicates to the mixings in which it is used a greater degree of tackiness and softness in an unvulcanised state than one usually meets with, even when the soft kinds of raw rubber are used. This is certainly an advantage in the case of certain mixings, but it necessitates the most stringent adhesion to the proportions of a mixing which has been found by trial to be satisfactory; for if the right quantity be exceeded to the smallest extent, the rubber may become so soft that it is impossible to work it, and after vulcanisation it may not possess the necessary elasticity. In Para mixings and others of approximately equal quality, such as are used for proofing many of the fabrics, neither pitch nor carbon-black is employed, but instead of these litharge is added; such mixings do not, of course, become black until they are vulcanised. Oil-black and gas-black are the kinds of carbon-black used; this pigment is the one for mixings which need show no particular polish, and which might also show up grey. An addition of more than $\frac{3}{4}$ per cent. of black is rarely necessary, since all these mixings also contain lead compounds; when pitch is present the black is added in still smaller quantities, and reduces the tackiness of the pitch in some degree.

Coming now to the manufacture itself, we see that the separate parts of which a rubber shoe is composed can be grouped under three distinct headings, viz. the sole, the upper, and the inside.

(a) *The Sole.*—The foundation of the shoe is with rubbers, as with leather shoes, the sole. This part is subject to the greatest amount of wear, and must therefore not only be made of tough, firm rubber, but must also be fairly thick, as much, sometimes, as 7 mm., the actual thickness varying according to whether it is a child's, a woman's, or a man's shoe. In all other kinds of rubber goods which are made up from sheet, sheet of such thickness is always built up from several layers of thinner sheet, because it is too difficult a matter to calender such thick sheets. The sheet rubber for the soles of shoes, however, is not only run on the calenders to the desired thickness, but these also impart to it the usual well-known pyramidal impression and the manufacturer's brand; moreover, the sheet has to be run of uneven thicknesses, because the instep and the heel are all in one piece with the sole; the sheet has therefore to be thickest at the heel and thinnest at the instep.

It will be clearly seen from this that the calendering of such sole-sheet presents certain difficulties. In particular, the calenders (fig. 84) must be of great strength, and therefore the rolls are comparatively narrow—only a little wider than the length of the soles. On the final roll are engraved the necessary markings, which are repeated at convenient intervals so as to leave room to enable each sole to be cut out well. Since a sheet of uneven thickness is to be calendered, the rolls cannot be run at equal speeds, but only in such a way that there is always plenty of rubber in front of the final pair of rolls, from between which the finished sheet, bearing the requisite makings, emerges. Furthermore, the rubber must be kept very warm, to ensure the sheet being absolutely homogeneous and free from air-bubbles. Nevertheless, if the rubber has been well-worked beforehand, and is kept warm, the sole sheet can generally be successfully run from the engraved rolls. The sheets then pass on to tenters, the size of which is regulated by the length of the cutting-out table or the cutting-out machine. Before the individual soles are cut out, the sheet is submitted to a certain treatment which is most advantageous, but in rubber goods is restricted to this instance and to the manufacture of unvulcanised Para strips for cables. This consists in dipping the sole-sheet for a short time (five minutes) into boiling water, the result being that during subsequent vulcanisation there is practically no perceptible shrinkage, and the shoe, which is stretched tightly on the last, is thus prevented from cracking and becoming distorted.

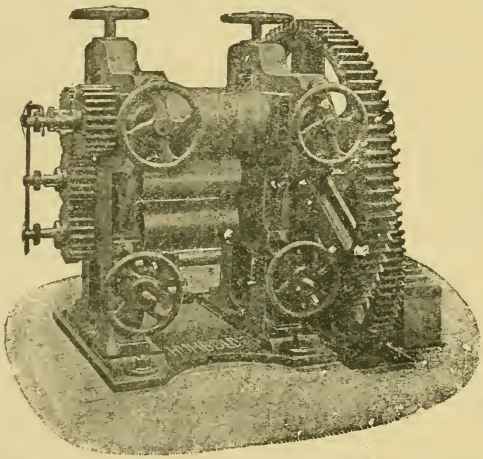


Fig. 84.

The soles are cut out either by hand or by machine, the advantage of the one method over the other being dependent upon the kind of trade done; for the machines, however ingeniously constructed, can in any case only cut out one sole at a time, because the edges must be cut obliquely to ensure a perfect join between the upper and the sole. Hand labour is just as certain as regards this detail, and when performed by skilled hands is very nearly as

rapid as machine labour. In both methods zinc templates, of size and shape corresponding to those of the shoes to be made, are used.

The following are current sole-mixings:—

A.	West Indian	5,000	gms.
	Reclaimed	2,500	,,
	Substitute (odourless)	2,000	,,
	Carbon-black	800	,,
	Litharge (free from peroxide)	2,500	,,
	Barytes	10,000	,,
	Whiting	30,000	,,
	Sulphur	250	,,

B.	Ceara Iα	4,000	gms.
	Substitute (odourless)	3,000	,,
	Carbon-black	800	,,
	Litharge (free from peroxide)	2,700	,,
	Whiting	25,000	,,
	Barytes	5,000	,,
	Sulphur	150	,,

Of course the sole mixing varies with the quality of the shoe.

(b) *The Upper.*—Like the sole, the upper includes several parts bearing distinctive names; the front part, the side pieces, and the back part, surround the whole shoe in a single piece. This does not get such hard wear as the sole, but, on the other hand, it is subject to a great deal of stretching, bending, and twisting, and must therefore be quite pliable, so as not to crack. Consequently the thickness of the upper need only be small; it is hardly ever more than 0·4 mm., and is generally just the same for all kinds of galoshes turned out by any one factory. An ordinary set of three-roll calenders is all that is required to run the sheet, but these should work absolutely smoothly and evenly. The slightest amount of vibration will result in the production of stripes and other inequalities in the soft rubber; of course these are to be found on other kinds of sheet, but are not so detrimental to its usefulness, whereas in this instance a smooth surface is the chief desideratum. The rubber should be particularly well mixed, and in this the soft nature of the mixing due to the pitch which it contains will be of assistance; otherwise it would need to be worked too long and heated too much to do it any good. The comparatively soft state of the mixing also determines the nature of the further handling of the sheet. The sheet is first of all not rolled up like others, because it would stick together; and even if a layer of cloth were run in between successive layers of sheet, the impression of the cloth and other roughnesses would be formed on the sheet when it had lain for a short while. It is therefore cut off as it comes from the calenders in lengths of 2 to 3 metres, according to circumstances, and the pieces are spread out on cloth-covered frames, which can then be packed on top of one another.

Calenders are also made which cut out the uppers direct, but, of course, the two rolls which carry the knives have to be changed for every different size of shoe. One cannot superimpose several layers

of sheet for cutting purposes, because the rubber is too tacky, and the use of chalk, which one would adopt in the ordinary way, is prohibited by the circumstance that the upper portions of the whole surface have afterwards to be stuck on. The upper parts must be carefully treated after being cut out, until they are used, each separate piece being placed between cloths bound together in book form.

The mixing for the uppers has the following composition:—

Peruvian Para	5,000 gms.	"Angel red"	1,000 gms.
Barytes	5,000 ,,	Sulphur	200 ,,
Lithopone	5,000 ,,	Carbon-black	200 ,,
Litharge (free from peroxide)	2,000 ,,	Pitch mixture	1,200 ,,

The "Pitch mixture" consists of—

Pitch	10,000 gms.	American resin Iα	250 gms.
Carnauba wax	500 ,,	Trinidad asphalt	50 ,,

(c) *The Inside.*—Under this heading are classed all those portions which are covered by the upper and the sole, and of which only the lining is visible in the finished shoe. All the parts belonging to this category consist, in order to give the necessary support to the galosh, of more or less thickly proofed materials, of the most varied kinds, such as webbing, canvas, cloth, and even wadding and fur. These materials are generally proofed on the calenders; in the case of webs, which are only very thinly coated, the spreading-machine may also be used. With regard to the quality of the mixings the following classification of the various parts can be made: inner-soles, half-soles, caps, heel-pieces, instep pieces, and the so-called German or Russian spurs. The mixings used are of the cheapest; they need be possessed of no remarkable properties, either because the fabrics on which they are spread are very strong, the rubber on them being only present as a cement to unite them to the other parts of the shoe, or because they have a double covering, and are sometimes, also, completely enclosed between other strong parts as a filling-up material. On the other hand, a certain amount of toughness is necessary, and this is produced by the admixture of fibrous material, the waste from unvulcanised proofed cloth being used for the purpose. The following mixing is about a standard quality:—

West Indian	10,000 gms.	Carbon-black	500 gms.
Reclaimed	15,000 ,,	Sulphur	600 ,,
Substitute, brown	10,000 ,,	China-clay	15,000 ,,
Pitch	1,500 ,,	Whiting	10,000 ,,
Proofed cloth waste	5,000 ,,	Borneo mixture (from Besk)	2,000 ,,
Litharge (free from peroxide)	12,000 ,,		

For the inner soles, as will be noticed in rubber shoes of quite different makes, red and light-grey cottons of various shades are in favour, but other fabrics are also used, in brown and other colours. The coating of rubber should be about 1 mm. thick. After they have been taken from the calenders the cloths are rolled up ready for cutting out. There are no special precautions to be observed in the latter process, and it is the general practice to punch them out by machinery, about 10 thicknesses at a time. The inner sole covers the whole length of the sole inside the shoe, whereas the half-sole, which comes between this and the outer sole, and corresponds roughly with the welt of a leather shoe, extends only from the toe to the instep. It has neither insertion nor outer layer of cloth; it is cut out by machinery, but also partly by hand, as are the instep pieces and the heel-pieces. The cap which surrounds the heel and forms the thickest part of the upper shoe may be as much as 5 mm. in thickness, and has fabric on both sides. Greater difficulty attends the cutting-out of this part and its preparation for use than is experienced with the parts already mentioned. For it must be sloped off quite gradually down to the two sides of the shoe which meet it in front, or uncomfortable ridges and sharp edges would be formed where the two parts join, that is, about one-third of the length of the shoe from the back. On this account the two front edges of the cap are cut obliquely, leaving a cut edge about 10 mm. wide which laps over the canvas of the side piece. This cutting can be done best by hand, because the caps for different shoes are of different thicknesses. The spurs which have been mentioned, and which are attached to this part, are cut out of sheet which has been run on calenders with engraved rolls similar to those on which the sole-sheet is calendered, with the individual spur-moulds at short distances from one another.

On account of the low quality of the mixing used, and of the great strain put upon the spurs when the galosh is being taken off, the spurs are covered by hand with proofed linen. This is intimately united with the rubber of the spurs by tightly pressing the whole for a few minutes in a heated press, the plates of which are provided with holes into which the spurs fit. The remainder of the inside parts are proofed with a different mixing. These parts include the lining of the upper, the web lining, the web sole, the toe-cap, the thin cap, and the proofed fabric which is used for covering over the seams. All these fabrics have a thin coating of a good mixing, which may be described as a Para quality with

a little litharge added; the following is the composition of the mixing:—

Para	1,500 gms.	Rape oil substitute (brown)	1,500 gms.
Manaos, negroheads .	500 ,,	Litharge (free from peroxide)	900 ,,
Kassai, Upper Congo .	5,000 ,,	Sulphur	300 ,,

The proofing is in each case on one side only. The lining of the upper consists, as a rule, of webbing of the same colour as that used for the sole lining, and is prepared for use in the same way. In both instances besides the fabrics mentioned, special linings are sometimes used, such as wool, wadding, and fur. The web lining is identical in size with the lining of the upper, and unites the latter with the upper itself. The same relation holds between the web sole and the thin cap. The toe-cap forms the toe of the shoe, and serves both to give strength and as an ornament, its shape being visible on the outside; it is generally heart-shaped. The proofed fabric used for covering over the seams is cut into strips about 6 mm. wide for use. A component part which is only occasionally used remains to be mentioned, viz. rubber-coated twine. This is used in the manufacture of rubber galoshes, the method adopted being to lay short pieces of it under the outer coating of rubber. It is prepared by dipping twine into rubber solution.

Two parts of the rubber shoe which occupy an exceptional position, and cannot be brought under either of the above headings, remain to be mentioned; they are the cap-lining and the so-called French spurs. Cap-linings are only used in making up men's shoes. They form the inside of the heel-piece, and are made from approximately the same mixings as the soles, the amount of raw rubber being increased, however, by a good 5 per cent. They are united on the outer side directly to the upper. The French spurs are made from a mixing which is very much the same as that from which the uppers are made, but which contains no tar. The sheet from which they are cut is run in the same way as that used for Russian spurs, and the spurs are also pressed in moulds in the same way, but they are not covered with cloth. They are fastened to the outside of the shoe by means of rubber solution.

(d) *Making-up.* — Just as the various parts of the shoe are carried to the cutting-out room on endless conveyor bands, they are taken in the same way, after they have been cut out, to the making-up room. The making-up of a rubber shoe is not at all a simple matter. An ordinary shoe consists of eight different parts, a high-buttoned shoe of seventeen parts, whereas, on the other hand, a rubber boot is made up of twenty-three parts, and not one

of these is superfluous. The most interesting part of the manufacture is carried out in the making-up rooms. Making-up is a difficult process, requiring accurate knowledge, and it is carried out almost entirely by female labour. First of all the separate parts, with the exception of the webs, are spread with solution, and the inside portions, in particular the linings of the uppers, are laid on the lasts. On top of these the caps are rolled down by means of the ordinary hand rollers as used in other parts of the factory, and then the inner sole is put on. The places where these meet, and in particular all inside seams, are covered with the proofed strip mentioned above, in order to make them more durable, but the seams must also be made perfect before this is put on. The half-sole is now put on, and then the instep-pieces and heel pieces, after these the web lining and, if required, the German or Russian spurs; the uppers, and finally the soles, are added, the French spurs being put on if required. All the parts must adhere firmly to one another without air-spaces between them, and without interspaces. The ornamentation seen on the upper is produced, so far as it is not due to the outlines of the toe-cap or to pieces of twine which have been put under the outer coat, by means of a small toothed wheel, which is also used to press the seams together. An average woman worker can turn out a maximum quantity of about forty pairs of shoes per day.

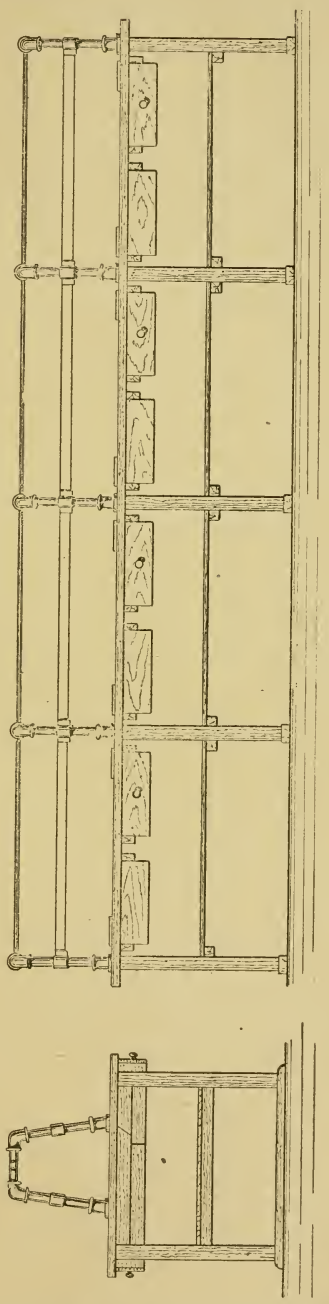


Fig. 85.

(e) *Varnishing.*—This is the final operation before the shoes are

vulcanised. The varnish itself is an important secret of every rubber shoe factory. A deep black, non-brittle, elastic varnish is difficult to prepare. It consists in general of linseed oil, litharge, and sulphur, with a little oil of turpentine, and is painted over the whole of the shoe, including the sole, by means of a large marten's-hair brush, the solution being made sufficiently thin not to froth. If frothing takes place the solution must be diluted. Varnishes containing a ready-made black ingredient, such as asphaltum, are not, as a rule, so valuable, and are generally used only for after-varnishing. In America shoes are varnished in the following way. The shoes are arranged on their lasts on iron racks, and are taken to the varnishing-room, where they are removed from the racks; the top edge is rapidly run over with the brush, and the whole shoe is then dipped in the thin solution of varnish, and immediately afterwards is put back on the rack. It is essential that the lacquer should not flake off, and the pliability of the upper is a valuable factor in this connection, since the varnishes make intimate contact

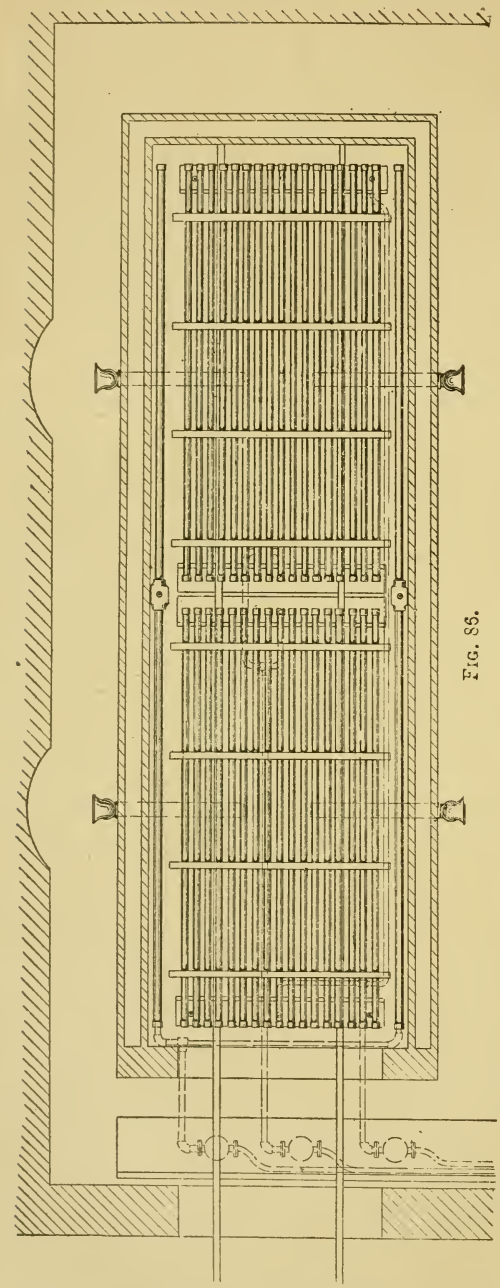


FIG. 88.

with it. The varnish has to go through the vulcanising process, and is therefore subjected to a very high temperature; all volatile constituents (with the exception of the very volatile benzine with which it was diluted) must therefore be completely driven off by heat before it is used, so that no vapours can possibly be given off during vulcanisation, and form blisters. In spite of this precaution a varnish may go wrong on heating so that to make absolutely sure that it is all right it is tested before actual use, by coating a small piece of the shoe rubber with it, and subjecting this to vulcanisation.

(f) *Vulcanisation of Galoshes.*—This is carried out exclusively

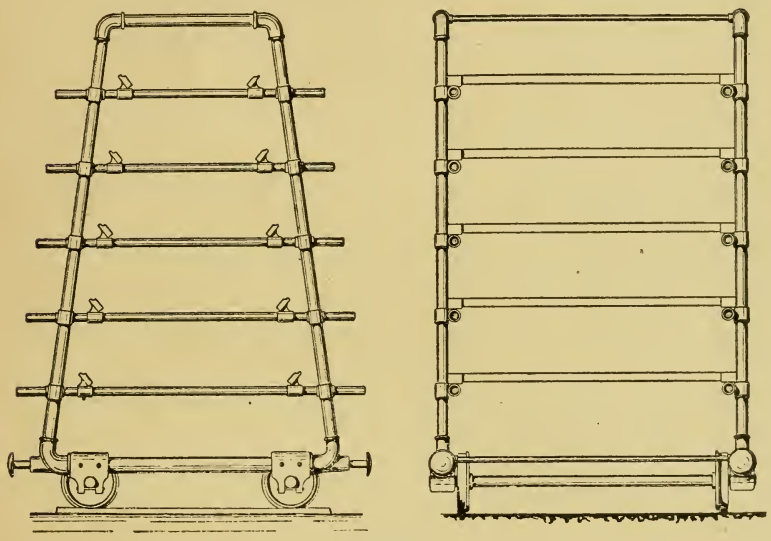


Fig. 87.

in hot-air chambers, since the shoes have to be cured without any protective covering. The stove is generally traversed by heating coils on the floor and walls (fig. 86). The walls should be lagged with some insulating material to prevent loss of heat, and so to enable the temperature of the chamber to be kept absolutely constant. Special care must be taken with the air-outlets, which must be distributed over the top of the oven in such a way that no variation of temperature is brought about in the process of drawing off the air from the chamber, for the temperature must be kept absolutely constant in every part of the oven. The rubber shoes are put on mandrels on iron cross-rods, supported on trolleys (fig. 87), on which they can be run into and withdrawn from the vulcanising chamber. As is always the case with hot-air vulcanisation, where the space is only slowly heated up, the length of time required for

a cure is comparatively long, from eight to ten hours being occupied in gradually raising the temperature up to 130° to 140° C., according to whether the rubber is quick- or slow-curing. This temperature must be maintained for at least an hour and a half, but must not be allowed to exceed 140° C.; in the first place, because the fabrics would begin to lose strength and change in colour; and, secondly, because the polish of the varnish would be dulled thereby.

The so-called "sulphuring-up" does not often occur with shoes; but when it does, its effect on their appearance is more objectionable than in many other articles; further, when insufficiently vulcanised the varnish may remain tacky. The temperature of the heating chamber is controlled by the use of a long thermometer; in order to make sure that vulcanisation is complete the chamber is provided with flaps through which test-pieces can be withdrawn. Before attempting to empty the chamber the foul air is exhausted from it; the trolleys are then run out into a room to cool down. When cool, the shoes are examined for defects, sorted, branded (generally with vermilion) and packed ready for dispatch.

16. **Manufacture of Insulated Wires and Cables.**—Except in the case of submarine cables, vulcanised rubber is at present used for the insulation of the metallic wires used for cables, etc.; the principal rubbers employed in the mixings used for this purpose are Para, Mozambique, and the best Congos. In this manufacture it is essential that the rubber should be very thoroughly washed; but the mistake should not be made of washing it for too long a time, and in too thin a sheet, since the rubber suffers by overworking on the washing-rolls. The rubber used should not be dried in the vacuum-drier; this point has been specially referred to in the chapter on the drying of raw rubber. The ingredients, French chalk, china-clay, and zinc oxide, must be well dried and sifted. In mixing, the formation of nibs must be avoided, and the rubber should not be worked for too long a time. For calendering the sheet the four-roll calenders, as specially designed by the firm of Haubold (p. 52) are employed, the chief aim being to avoid the formation of blisters; to achieve this the mixing must be well warmed up and calendered immediately. The calendered sheet is allowed to remain wrapped in its cloth for at least a day to cool down, and is then lightly chalked on the machine already described. The most usual and the most convenient method for covering the copper wire is by pressing the rubber round it in the coating machine (shown in fig. 88). This machine has been introduced everywhere, and as many as twelve wires, or even more, can be

covered by it at a time. The ordinary machines in use are those with three pairs of rollers, but there are others with as many as six pairs, with diameters between 150 and 250 mm., and breadth of face from 100 to 200 mm. Working under normal conditions, the rollers are driven with a peripheral speed of from 7 to a maximum of 19 metres per minute. The speed of the apparatus for carrying away the cable as it passes from the machine must be capable of regulation, and the cable should not be drawn away faster than it is paid out by the machine, or both wire and covering will be weakened, and the rubber insulation may leave the wire

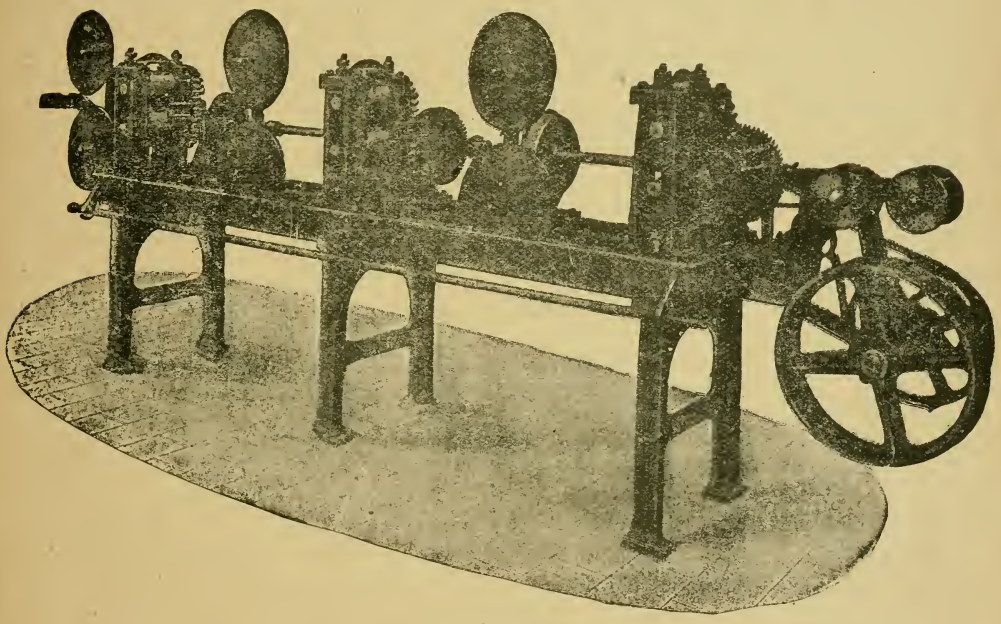


Fig. 88.

or be torn off. The circular knives must be turned clean and free from notches, otherwise the covering will not be very reliable. Again, the rollers should not be set up too tight. The sheet to be used for covering, which is from 0·2 to 0·3 mm. thick, is run free from blisters on the calenders, cooled down, and then rolled round cylindrical mandrels and cut into rolls of strip of the desired width, on automatic lathes. These rolls are inserted in the covering machine; the wire passes between two plates through the first pair of cutting rollers, and above and below the wire are run strips of rubber from the rolls inserted in the machine, and the wire is thus covered by the strips. The wire and its covering pass between the cutting rollers, running in grooves on their surfaces, where com-

pression takes place, and the excess of rubber is cut off at the edges by the pressure of the sharp edges of the roller. On leaving the first pair of rollers the wires pass on to the second pair, where the second coating of rubber is put on, and so on for further coats of rubber. The wires run through fine steel combs, which separate the cut edges from one another, and from these to the drums, on which they are wound evenly and without tension by means of the winding apparatus.

For ordinary insulations, machines similar to tube machines may be employed. Dr Baur's assertion that only inferior qualities can be run on such machines is not accurate; the better qualities can also be dealt with if the rubber mixing is properly treated and suitable additions of ceresine and vaseline are made. Thin wires are wound in layers on slightly tapered wrapping-drums and then vulcanised, but the stouter sizes must first be lapped round with tape, proofed on one side, on a special machine, so that the insulation may not get pressed out of shape and become one-sided.

Vulcanisation is best carried out in the autoclave (fig. 32), for it is of great importance that the steam throughout the heater should be dry, and should circulate uniformly round about the wires wound on the drum; that this result cannot be attained in the ordinary heaters must be known by everyone who has had to deal with them, and is easily shown to be the case by determining coefficients of vulcanisation. The drum being mounted at a sharp angle to the horizontal, and kept in motion, prevents the formation of steam banks in the heater, and in consequence the wires do not come into contact with wet steam in the lower part of the heater. For this reason the insulation absorbs a comparatively small amount of water, and the insulation resistance of the conductor is higher than in the other case. In addition to this, vulcanisation is completed more quickly on account of the more thorough circulation of the steam in the heater, and immediately the cure is completed the wire can be dried *in vacuo* in the same heater. To obtain a uniformly good insulation resistance it is most important that the rubber be correctly vulcanised; in no case should it be left too soft.

Mixings for cable insulation should contain rather a large percentage of pitch which has been heated at 225° C. For high-tension cable this is strictly necessary, the rubber being rendered more homogeneous thereby. The addition of pitch to the mixing has the effect of enabling it to be run out into a firm, very dense sheet, of low porosity, even if it contain a considerable percentage of brown substitute (white substitute must not be used in cable

mixings). Brown substitute should not be despised as an ingredient of such mixings, more particularly if it be made from high-grade blown oils. In cable mixings, differences in insulating power result from uneven distribution of the compounds in a mixing, and the aim in preparing such mixings should be to make the "breaking-down" and the insulation resistance in different parts of the cable equally good. The results obtained by these two methods of testing should not greatly differ from one another. For this reason care should be taken to produce a homogeneous mixing by the addition of pitch, and to carry out the mixing process in such a way that an almost air-free admixture of the ingredients is brought about; the attainment of this end is assisted by the addition of pitch which displaces the air contained in the pores of the rubber.

17. **Compositions of Asbestos and Rubber.** (a) *Vulcanised Asbestos.*—This insulating material consists of asbestos fibre felted together with rubber and mixed with pigment and other fillers. By intimate subdivision of the asbestos fibre a felted sheet is formed which answers the highest requirements of electrotechnics.

This sheet can be made in the following way:—The washed rubber indicated in the mixing given below is dissolved in a Werner-Pfleiderer machine in 35 kilos. of light benzine. The other ingredients named in the mixing are then gradually added to the rubber solution, and the whole mass is worked until a homogeneous solution is produced, a process which may occupy about two hours. When that is complete, and not till then, the finely frayed-out asbestos fibre is slowly added in the form of fluff, and the whole mass is again worked for about an hour on the machine. When the mass is thoroughly mixed it is spread out in large frames, the benzine evaporated off in the vacuum chamber, and the sheet dried. The sheets are then put between zinc plates in a hydraulic press, where they are subjected to a pressure of 40 kilograms per square centimetre. Finally the sheets are passed through the glazing calenders, and are ready to be used for making magnet bobbins, rollers, and sounding-boards. The articles are afterwards vulcanised; the sheets may also be vulcanised as such in the press, under hydraulic pressure.

Specimen Mixing.

Massai	2,500 gms.	Barytes	4,000 gms.
Columbian	2,500 ,,	Japan red	4,500 ,,
Substitute (free from smell)	2,000 ,,	Zinc oxide	4,500 ,,
Waste	2,000 ,,	Linseed oil	1,000 ,,
Sulphur	2,500 ,,	Magnesia usta	500 ,,
Golden sulphide	4,000 ,,	Asbestos fibre	16,000 ,,
China-clay	4,500 ,,	Burgundy pitch	1,000 ,,

A second process is based on the use of papermaking machinery, the "solution" being dried off on the steam-heated drums, and the mixture cut off in the form of a cylinder when it is thick enough.

(b) "*-Ite*" *Compositions.* — The demand for ordinary rubber packing-sheet for steam-packings has fallen off, as the practice of using superheated steam and high pressures has grown amongst engineers. At steam pressures of twelve atmospheres and at temperatures of 180° to 186° C. ordinary rubber packing-sheet cannot be used, since it is no longer able to meet the demands made upon it.

In recognition of this change, in consequence of which a more resistant packing material became a necessity, attention was turned to new compositions, and the result was the "-ite" sheets, which satisfied all requirements. The sheets as a class were given this name in consequence of the number of names ending in "-ite" given to different makes by the firms which made them, *e.g.*, Klingerite, Moorite, Metzelerite, Cooperite, etc. (The name "Itplatte" itself has recently been protected by the firm of Gustav Adolph, Biebrich-a.-Rh.). Indeed, blind competition has in this instance, as in others, brought this composition, in principle a good one, to the very limits of possibility within a very short time, and converted the quondam speciality into a staple article of rubber manufacture, a state of affairs which is of no more benefit to the consumer than to the producer. The "-ite" compositions consist essentially of a thoroughly felted mass, in which asbestos is used by preference as the fibrous material. But it is not a matter of indifference what kind of asbestos fibre is used. Blue Cape asbestos has proved to be the most resistant towards high temperatures. Next on the list comes Siberian asbestos, and this is to be preferred to the Canadian product. The staple of the fibre is also an important point to be considered, and only samples with long fibres should be used. Waste fibre from spinning, which is in part richly mixed with cotton, is not to be recommended for the production of a good sheet, the fibre being too short, on account of the frequent carding and willowing to which it has been subjected, and so giving rise to an imperfect felting. The composition is the better the more intimately the fibre is mixed and bound together. For similar reasons hand-picked asbestos sheet is to be preferred to machine-made sheet. As regards other ingredients, "-ite" sheets generally contain quantities of mineral fillers, such as china-clay, barytes, talite, iron oxide, etc., according to quality. On the other hand, the

rubber content is rather low, the rubber acting mainly as a cement. Hydrocellulose is a particularly suitable ingredient.

It is clearly and easily conceivable that packing of this description must be able to withstand not only high temperatures but also the high steam pressures which are now usual everywhere; because, indeed, the packing actually consists merely of an intimately felted mineral mass, to which a somewhat elastic, leathery grip is imparted by the rubber cement, and so it cannot be forced out between the flanges. A further advantage is the mechanical stability of this kind of packing. It has already been rolled out and firmly compressed in the course of manufacture, and therefore cannot alter very much afterwards in tightening up the flange bolts; these bolts, therefore, do not require continually tightening up. The composition vulcanises in a few minutes between the flanges, and so forms a safe packing which can only be damaged by blows.

Why the most inconceivable additions should be made to such a simple composition passes comprehension, and reminds one of the early days of rubber manufacture. Why, in fact, employ purposeless additions, only to add mystery to the subject?

Two different methods are available for the manufacture of these sheets, but a preliminary mixing in the dough mill is common to both. The masticated rubber which is to be used is, first of all, dissolved in benzine, and the thin solution obtained is mixed in two lots with the mineral ingredients, a homogeneous paste being formed. Into this the loose, carded asbestos fibre is introduced, and the whole mass is worked until it is thoroughly felted together. The more thoroughly the mixing is done the more homogeneous will be the resulting composition. We consider it very advisable to first card the fibre before adding it to the mixture, and recommend the use in connection with the mixing-machine of a small special opener with a belt conveyor to carry away the carded fibre. By this means the fibre can be mechanically added to the mass in a uniform way in the form of a light fluff and not balled up together; this leads to more efficient felting.

The methods of working up the mixed compound into sheets are as follows:—The sheet can with advantage be either rolled round the rolls in single layers, the ends of the length being then brought together and the sheet "doubled" up to the desired thickness, or the special "-ite-sheet" rolls made by Haubold, and shown in fig. 89, may be used. On these rolls sheet up to 3 metres in length can be made. On the rolls shown in fig. 89A, on the other hand, it is

possible to work sheets as much as 5 metres in length, one after another, without having to build up from a number of thin layers.

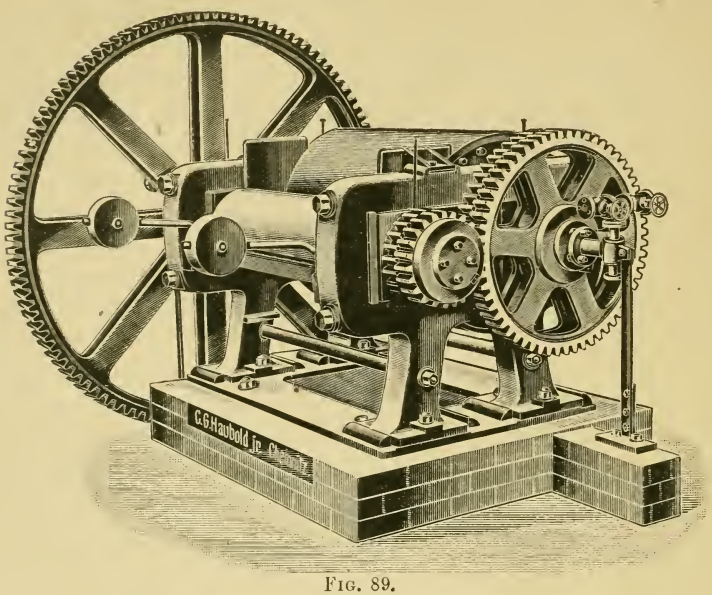


FIG. 89.

In principle the manufacture is similar to that of asbestos sheet. The stiff pulp on leaving the mixing-machine is rolled out into

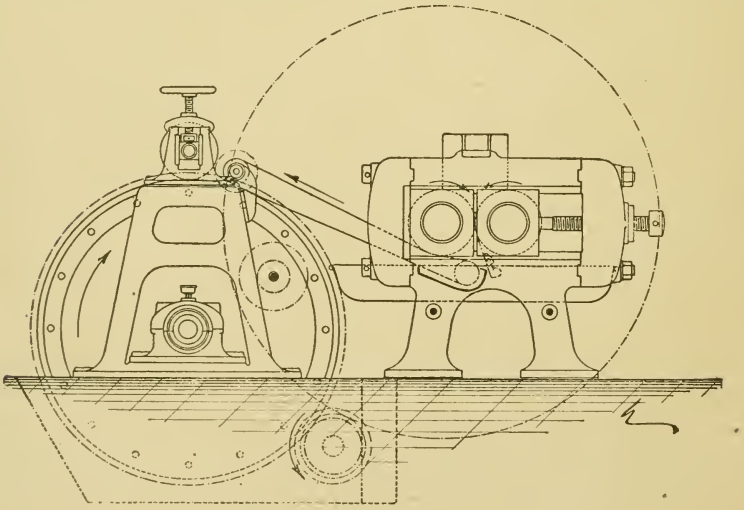


FIG. 89A.

wide sheet between the cylinders, taken up by the conveyor, and carried forward to the large cast-iron roll. Here the thin sheet is

firmly pressed by the press-roll on top. As soon as the correct thickness is reached the sheet is cut off and removed. The rolls are provided with arrangements for heating and cooling them, and also with a spreading-knife and carrier rollers; the metallic conveyor passes through a containing vessel where, if necessary, it can be kept moistened. By this means a solid "-ite" sheet is obtained, consisting of thin separate layers intimately felted together. In both cases the sheets are afterwards subjected to pressure in large hydraulic cold presses, in order to produce a hard sheet.

18. **Eraser Rubber.**—The manufacture of this article is carried out in the following way:—Mixings of suitable composition, containing as fillers chiefly pumice powder, glass powder, whiting and barytes in large quantities, are calendered into sheet and doubled up to the requisite thickness as described on pp. 54–56.

The sheet, which should be free from blisters, is compressed in metal moulds measuring 60 × 60 cm., which are provided with the various impressions which it is desired to reproduce on the rubber. A cold press is all that is necessary for this purpose, and in it as many as twenty moulds or more can be dealt with at a time, the pressure being maintained for about three hours. The compressed sheets of rubber obtained in this way are cut up and vulcanised in chalk at a low temperature. Another method is to vulcanise the roughly-calendered sheet in the moulds in a multiple press. Qualities containing much waste give better results when treated by the latter process, for in the first method of production the impressions on the rubber turn out indistinct and not so sharp as is desirable, this defect being enhanced during vulcanisation by the shrinkage which then takes place.

Union rubber—that is, rubber consisting of two different qualities (one for rubbing out pencil and the other ink marks)—is prepared in the following way:—The sheet, pressed smooth, is cut up on the lathe into strips of suitable width, attention being mainly directed towards getting a clean cut. The cut edges are allowed to dry, and are then given two coats of a good vulcanising solution. This is allowed to dry off, and the strips of the two kinds of rubber are then stuck together alternately, compressed, and vulcanised in suitable frames under the press.

These various kinds of eraser-rubber are cut up in automatic cutting presses with smooth- or saw-edged knives, it being unnecessary in these machines to mark out the separate sizes.

Another kind of eraser-rubber comprises the polished varieties, such as "Velvet" and "Diamond" American rubber, pointed

rubbers, etc. "Velvet" rubber is cut from sheet, and the pieces are rubbed down in a revolving drum, which is best made with a hexagonal section, and contains powdered pumice. The shaped, so-called, "Diamond" rubbers have first to be buffed on an emery-wheel, each piece being separately pressed into a wooden holder and held down on the wheel. In this way all the pieces are obtained of exactly the same shape and size. Pointed rubbers may be cured in moulds and then tubbed, or they may be cut out of sheet and smoothed down and pointed on special machinery.

Grease rubber consists of a mixing containing considerable quantities of dry white substitute and vaseline. Marbled rubber is prepared by the non-homogeneous mixing and calendering of mixings of different colours. *Radifix* is essentially only a chloro-sulphide substitute containing magnesia, and has nothing in common with rubber.

It was formerly the practice to use ordinary rubber stamps for braiding the pieces of rubber, but the whole sheet is now printed in a press or by means of a roller.

19. **The Manufacture of Para Sheet and Elastic Thread.** — The oldest method of making these goods, and the one still the most widely used in the special factories which deal with them, consists in spreading them on the spreading-machine (as opposed to calendering the sheet). Both methods are equally difficult to carry out, and good results are only possible after long experience and with the help of a well-trained *personnel.* It is also essential that only first-class raw material, consisting of selected "old Para" of the highest quality, should be used. It is by no means a matter of indifference what kind of Para is used, as is often incorrectly assumed even by specialists. The Para used should contain less than 2·8 per cent. of resin, a figure which would indicate that the latex was obtained from very old trees, and which would ensure a high degree of elasticity. The protein content should not be higher than 2·6 per cent. A good quality for sheet and thread should stand the following test:—A piece of the rubber 0·2 mm. thick and 50 mm. long by 10 mm. wide, should be capable of extension to 570 mm., and should recover its original length, on releasing the tension, to within from 3 to 8 mm. When the raw material has been selected it is washed and dried, as described in an earlier chapter, but obviously vacuum-drying is excluded in this instance, for well-known reasons which have been already discussed in Chapter II., p. 34. When dry, the sheet of rubber is run through a cleansing machine as a safeguard against the possible presence of any

particles of dust and other impurities, and only when the process is completed is the rubber subjected to mastication and mixing on the rolls with sulphur. The rolls should not be worked too hot at first, or the finely-powdered sulphur may melt on the rolls and form granules or crystals. The addition of sulphur being completed, the rubber is rapidly worked between hot rolls, so that the process may be completed as quickly as possible. The mixing and working on the rolls necessitate great watchfulness on the part of the workman.

When the mixing is completed the actual preparation of the calendered or spread Para sheet commences.

(a) *Calendered Sheet.*—The calendering of this sheet requires, in the first place, a carefully selected, capable *personnel*, and, secondly, a set of four-roll calenders of the best construction, which alone can find use here. This machine should in particular run quietly and smoothly; the rolls should be highly polished and as smooth as glass. The central adjustment for the rolls is so arranged that the third and fourth rolls (the two uppermost) can be adjusted, not only individually, but also both at once from the middle roll (the second), which is mounted in fixed bearings and serves as the driving-roll. The fourth (bottom) roll is also capable of being moved downwards. In connection with the third roll the necessary double-wedge adjustment, which serves as an arrest, and prevents the vibration of the rolls, should be looked for. In that way the bank of rubber between the second and third rolls is kept equal; otherwise the third roll would be lifted by the rubber against the fourth roll above it, a state of affairs which would be very detrimental to the uniform solidity of the sheet. The spindle of the roll-adjusting apparatus should not be in front of the rolls, but above the lower end of the frame top, since the rolls must be easily accessible. In front of the calender-rolls, which should always be regulated to a constant temperature with the aid of thermometers, are small, easy-running rollers over which the sheet can be drawn away. The four-roll calenders illustrated in the chapter on calendering (p. 52, fig. 24) are, up to the present, the most perfectly constructed set which it is possible to get for the purposes of this branch of manufacture.

In making this sheet it is not at all a matter of no importance at what temperature the rubber is introduced into the calender-rolls, and variations in the different batches among themselves should also be avoided. The temperatures of the rolls, too, should not differ, since apart from the so-called star-markings and blister-

formation, the rubber molecule also suffers, and this again reacts upon the vulcanisation, and shows itself in the extensibility and the tensile strength. The sheets, which show unequal constants in other respects, would then be very liable to undergo partial premature decomposition. The temperature to be employed must be regulated according to the kind of Para used, the kind of treatment it has already received, and the thickness of the sheet.

Sheets from which thread is to be cut are made from doubled-sheet run on cloths such as are used in the spread-sheet manufacture, and which will be described more fully later. The sheet is doubled in the way described on p. 52, and is afterwards dealt with and vulcanised, as described in the next sub-section.

(b) *Spread-Sheet.* — As mentioned at the beginning of this section, spread-sheet is that most commonly made in Germany. This kind of sheet has admittedly its advantages, but is a good deal more costly to produce, on account of the enormous consumption of benzine by which it is attended, and the greater amount of labour involved. The homogeneity and purity of the sheet made by this process can hardly be attained by any other method. The statement made by Baur on p. 270 of his book *Elektrische Kabel*, that spread-sheet may be recognised by its lack of cleanliness, is quite incorrect. In the manufacture of spread-sheet the place of the calenders is taken by the spreading-machine shown in fig. 72. For a daily output of 120 kilos. of sheet four spreading-machines are generally considered necessary, and in addition to these, and the washing- and mixing-rolls, a three-chambered masticator 720 mm. long and 750 mm. in diameter is required, together with two solution-mills.

The process of manufacture is in this case as follows:—The masticated rubber is dissolved in benzine in large tins, and then worked up on the solution-rolls or mills until a clear solution, free from lumps, is obtained. This solution is diluted with benzine to a degree dependent on the quality and thickness of the sheet.[1]

The rubber is spread on specially prepared cloths. The closely-woven fabric used for this purpose is impregnated in a special machine with shellac, and the rubber is then spread on the smooth coat of shellac exactly as described in section 12. When the sheet is finished it is stripped off the cloth on a stripping apparatus, and is chalked and vulcanised. The shellac-coated fabric must be washed out as soon as it has been used, and impregnated anew with shellac.

[1] *Cf.* also the exhaustive article "Gummilösungen" in *Gummi-Zeitung*, 1906, xx. p. 1204.

Spread-sheet is cured in the same way as calendered sheet.

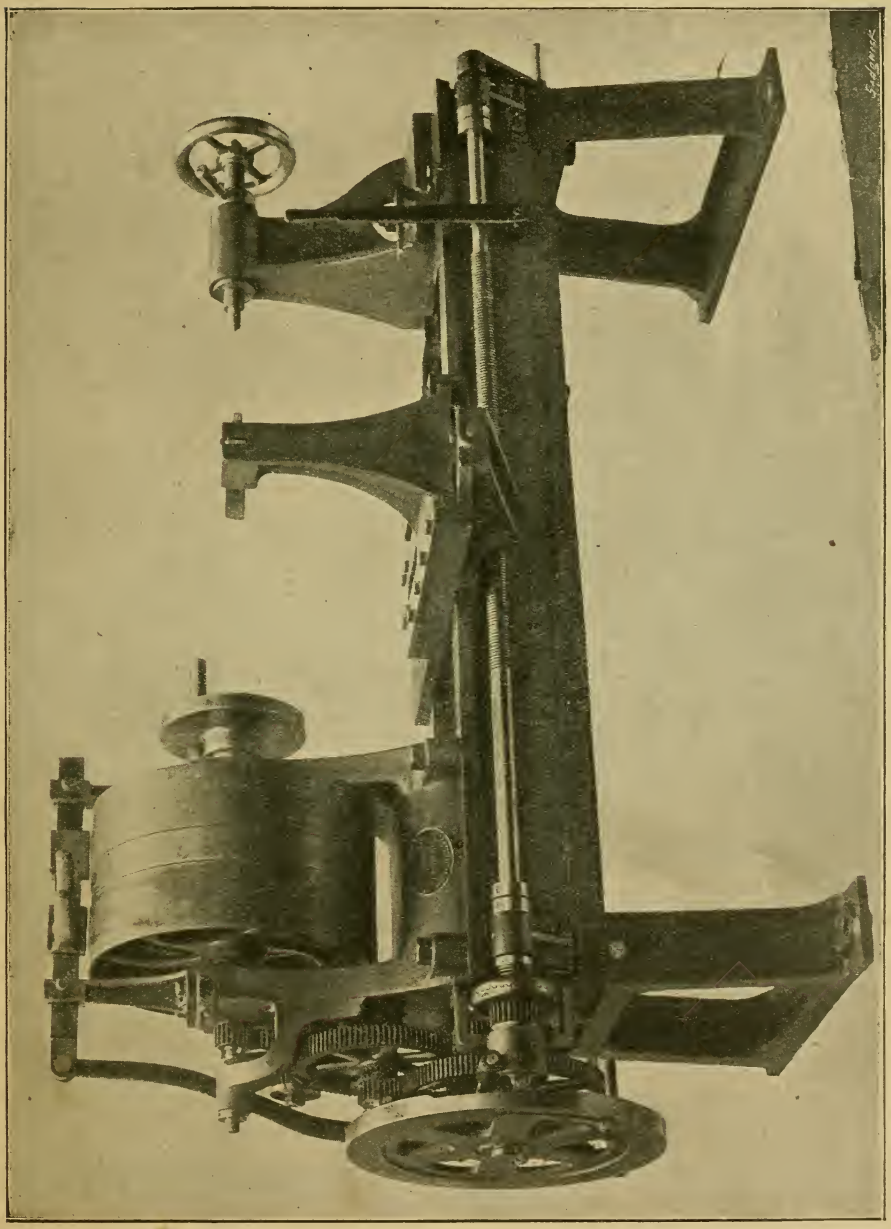


FIG. 90.

Para-proofed twill is used as a wrapping-cloth for this material, though, of course, it can only be used two or three times, after

which it is sold as waterproof cloth. The vulcanisation is carried out in a water-bath at $2\frac{1}{4}$ to $2\frac{1}{2}$ atmospheres pressure, care being taken to keep the temperature constant.

After vulcanisation the sheet is unwrapped and washed.

For thread-cutting the automatic cutting-machine shown in fig. 90 is employed, with drums 450 mm. in diameter and 700 mm. long, on which the sheet, lightly coated with shellac, is rolled. On an average six such machines are required to cut 120 kilos. of thread per day, and three men are required to attend them. The cutting is followed by boiling-out (to remove free sulphur), drying, sorting, and tying into bundles, special care being taken with the boiling-out process. The drying-room should be kept well ventilated and dark.

CHAPTER V.

MANUFACTURE OF EBONITE.

HANCOCK is generally looked upon as the originator of the *manufacture* of ebonite. He patented his process for the vulcanisation of rubber by means of sulphur towards the beginning of the year 1843 without prejudice to the fact that Goodyear had already obtained the substance "hard-rubber"; Goodyear, however, had not gone so far as to prepare useful articles from it on a manufacturing scale.

For a long time, however, nothing more was heard of the process, since the various experiments made did not turn out favourably enough when they came to be put into practice. It was in 1851 that Goodyear, realising the importance of ebonite, took up his experiments again and succeeded in preparing a substance which was very suitable for articles in which, in addition to elasticity, the qualities of durability, ease of working, and chemical stability are essential. Goodyear's ebonite of that date consisted of a mixture of Para, magnesia, whiting, shellac, lead or zinc salts, and sulphur, these ingredients being intimately mixed together and run out into strips which were vulcanised at a fairly high temperature. The product obtained was dark in colour and hard, similar to jet or horn, and lent itself to being worked quite well. Gradually Goodyear omitted from his composition all the fillers except sulphur, his mixing now consisting of rubber and sulphur only; at the same time he raised the temperature of vulcanisation to about 165° C., and so arrived at a perfect ebonite. The problem still remained of finding a material with which to cover the plastic hard-rubber composition before vulcanisation, and with the discovery by L. Otto P. Meyer in 1854 that tinfoil was eminently suitable for this purpose, ebonite manufacture took its place amongst the industries in which manufacture in bulk can be successfully carried out, and, advancing steadily, soon won for itself a large market.

For these reasons Charles Goodyear and L. Otto P. Meyer must be regarded as the real founders of the hard-rubber industry.

Hard rubber, also called ebonite or vulcanite, is highly vulcanised rubber containing a large proportion of sulphur. The best qualities consist merely of rubber and sulphur. In the lower qualities, however, ebonite waste, ground to dust, is also used, together with mineral and other compounds and rubber substitutes, which are enumerated below.

Ebonite, unless otherwise coloured by the addition of pigments to the mixing, is of a rich deep black colour; it is capable of taking a high polish, and is easy to work mechanically; it is powerfully electrified by friction, and is a good insulator. It is diathermanous (transparent to heat rays) in a considerable degree, and its refractive power for radiation is high. Its refractive index is nearly as high as that of flint glass, and reaches as high a value as 1·56; its specific heat is 0·331249; its mean coefficient of expansion between 0° and 18° C. reaches 0·0000636, its coefficient of cubical expansion being greater than that of mercury at increasing temperature. The more important chemical behaviour of ebonite is in line with these well-known physical properties. It is very stable towards chemical reagents, more particularly when it contains no other ingredients than rubber and sulphur. To this indifference towards the action of acids and alkalies hard rubber owes its great importance and usefulness in chemical industry, especially in the form of pipes for conveying acids, and of vessels of different kinds. In a compact mass it is very stable towards air, light, and changes of temperature; it can be softened in hot water, and in this condition can be easily bent; on prolonged heating above 180° C. it loses its valuable properties and slowly carbonises, yielding no intermediate products in the process. It swells up slightly in carbon bisulphide and in coal-tar solvents, but does not dissolve appreciably in them; in general it is very stable towards most solvents of rubber.

The valuable property possessed by ebonite of becoming slightly soft when heated and when in that condition of taking up slight impressions, which become fixed on cooling, is made use of in the manufacture of embossed sheet, which may be very varied in form and design, and is a valuable manufacturing material for a number of trades.

The actual technical manipulation of this article will be very thoroughly dealt with in the following pages, for the manufacture of ebonite is one of the most difficult branches of the rubber industry.

The raw material for use in this branch must be purified with

the very greatest care, and in particular the raw rubber. The reason for this is that when the ebonite comes to be polished later on any small particles of sand or dust which may be present become evident as projections from its surface. Hence it is necessary as a prime condition for success that the shops in which ebonite goods are made up should be absolutely dust-free.

The manufacturing process consists of the following stages:—

1. Mixing the rubber compound.
2. Rolling into the form of sheet.
3. Making up the various articles.
4. Vulcanisation.

And in addition there is the working up of the finished articles (on the lathe, etc.), milling, etc., buffing and polishing or rubbing down with oil. The process of mixing is carried out in exactly the same way as in the case of soft-rubber mixings. The washed rubber used, which must be absolutely free from sand, may be either Para, Columbian, Congo-Lopori, Madagascar, Borneo, or good Niggers, etc., according to the quality. Of these sorts, that which, after Para, gives the best deep black polish, is Madagascar. The sulphur, which is the most important ingredient added to the hard-rubber mixing, should be mixed into the rubber as uniformly as possible. The points of greatest importance in connection with the sulphur itself are, first, its fineness, and secondly, its freedom from acid, which has a most unpleasant effect upon hard-rubber mixings, particularly those which do not contain magnesia usta or other neutralising agent. Flowers of sulphur nearly always contain traces of acid, and on storage will often become still more strongly acid; this conditions the presence of a certain amount of moisture which leads to the production of porous, badly-marked aud faulty goods. Freedom from grit is also a most essential quality in the sulphur to be used, particularly in the case of goods which have afterwards to be polished. In mixings of lower quality finely ground hard-rubber waste—dust—is an important ingredient, and the preparation of this material should be most carefully supervised. On account of its importance the preparation is described separately in the following section.

Preparation of Ebonite Dust.—The ebonite waste is sorted into the following classes:—

1. Waste capable of taking a polish, consisting of rubber and sulphur only.

2. Waste capable of taking a polish, containing rubber, sulphur, and hard-rubber dust.

3. Waste not susceptible to polishing, containing mineral ingredients.

This system of classification cannot, of course, be strictly carried out; in class 1, for example, waste containing a certain amount of oil or resin may also be included without disadvantage. Class 1 waste is used in mixings for polished goods, class 2 waste for lower quality polished goods, and class 3 for "mechanical" ebonite goods which are finished without a polish. It is in the nature of things that, generally speaking, every factory works up its own waste to the best advantage, and waste bought in is consigned on sorting to a lower class, for safety's sake, albeit that owing to the employment of trade marks it is possible to appraise waste branded with certain marks at a higher value, just as in the case of old rubber shoes.

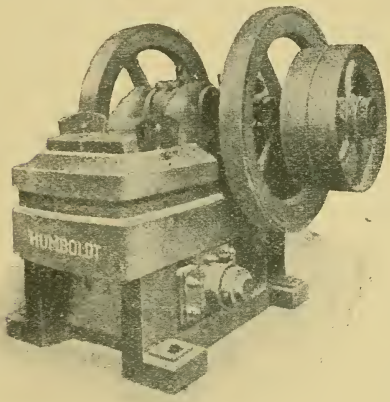


FIG. 91.

The sorted waste, after being broken up into small pieces in the stone crusher (fig. 91), is introduced into a boiling dilute solution of caustic soda, in order to remove any dirt adhering to it. The small fragments are then washed and dried, and passed on to the "Kaiser" mill (fig. 92), which mills them into very small granules about 1 mm. across. This machine is most conveniently raised up on a pedestal, which is closed in all round and into which the milled waste passes, the "Kaiser" mill throwing out the granules at the bottom through fixed, interchangeable steel grids. The hard-rubber shot obtained in this way is now transferred first to the simple but powerful milling-machine, with rolls 500 mm. in diameter and 60 cm. long, shown in fig. 93. The rolls can be steam-heated or water-cooled. The main condition for obtaining powerful friction between the rolls consists in correctly choosing the speed ratios of the drive, otherwise the consumption of energy may reach as high a figure as 50 h.p., which would render dust manufacture a very costly business. A hopper to take the material to be milled is fixed above the rolls. The hard-rubber granules are milled until a product as fine as flour is obtained, the rolls being closed up gradually during the process. This flour is, however,

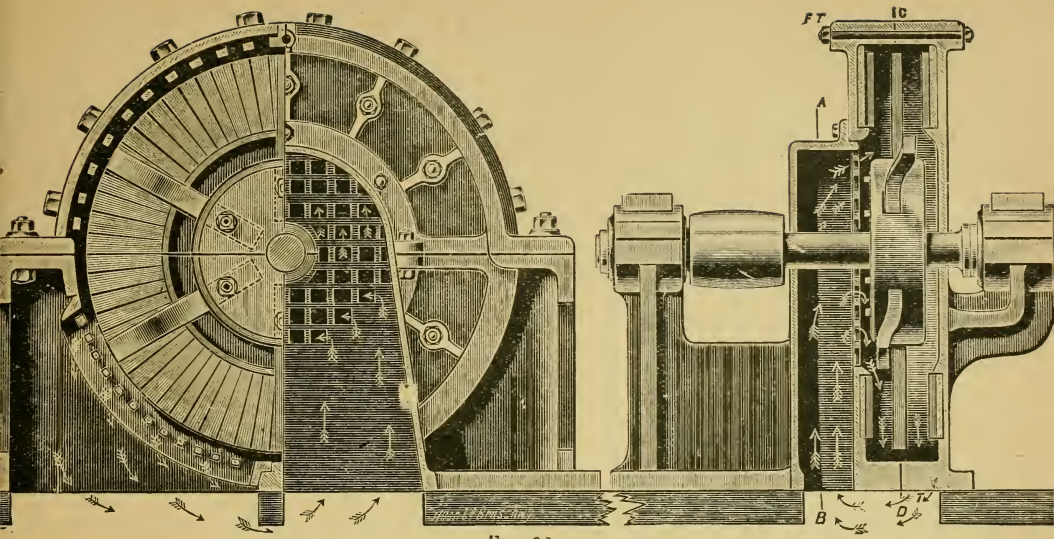


FIG. 92.

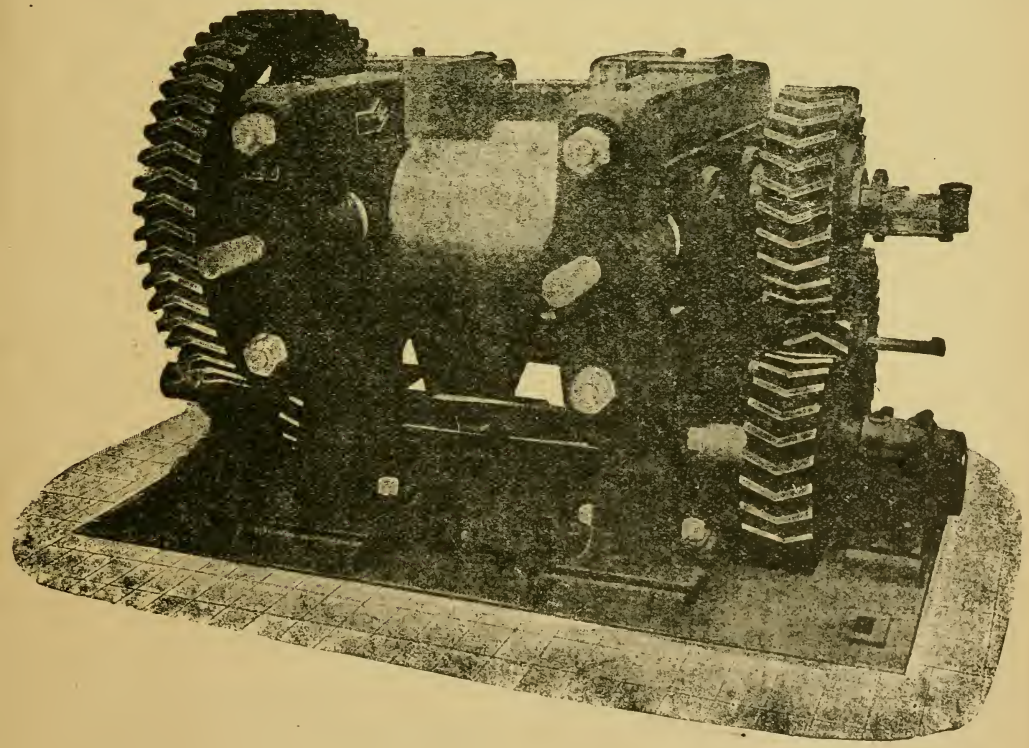


FIG. 93.

always mixed with coarser particles from which it must be separated by means of a blast of air or by centrifugal action. For this purpose the plant employed consists of a ventilating shaft together with means for producing the air-blast, and space for separating out the coarser particles, allowing the fine dust to pass on to the filtering shaft. The hard-rubber flour to be separated is drawn by means of an exhaust-fan from the chest below the milling-rolls through a trunk, and falls into a hopper placed close up to the ventilating shaft. Two smooth wooden rollers close the mouth of the hopper, and as they revolve allow only so much of the ground ebonite to pass through as they can distribute. A special fan blows a blast of air into the fan shaft, which can be regulated by means of valves, and this passes through the valves to the outlet, taking with it at this point the powder falling from the hopper. The fine dust is carried forward some distance before settling to the ground, while the coarser dust drops in the neighbourhood of the hopper, and is returned to the mills to be re-ground. On the other hand, the fine dust is carried forward by the air up to the filter, where it collects on the filter flannels, while the air after passing through a "Cyclone" is led into the shaft and so away. In this way two kinds of dust are obtained, one of which the finer, is used in mixings of a corresponding quality, while the other sort is used only in ordinary polished qualities. Instead of this air-separation method, the centrifugal machine can be used for separating the dust. This machine, illustrated in fig. 94, in addition to the basket, has inserted a fine wire sieve and a flannel filter. These centrifugal machines are specially made for the purpose by the firm of Haubold. The details of procedure are of a very simple nature, and need not be described. Before, however, the dust is ready to be added to the mixing it is tested on a wire sieve, and filtered through a magnetic sieve so as to remove every particle of iron from it.

1. **The Ebonite Mixing.**—In the case of the higher qualities the ebonite mixing consists roughly of the following ingredients: –

A. Para	10,000 gms.	B. Para	2,000 gms.
Sulphur	3,000 ,,	Madagascar	3,000 ,,
Linseed oil	200 ,,	Sulphur	2,000 ,,
Wax	250 ,,	Linseed oil	200 ,,
		Wax	500 ,,

In the case of Para the amount of sulphur is not allowed to exceed the percentage given, since it has been found a suitable one to transform Para into ebonite by vulcanising for six hours in the water-bath, with steam at a temperature of 135° C., slowly rising,

during the last hour of heating, to 140° C. The results of a series of experiments with different kinds of rubber, mixed with ebonite dust and sulphur, are given in the tables which follow. From these tables it will be seen that with a constant percentage of sulphur a longer time of cure did not give equally good results, but that in order to effect this the amount of sulphur had to be increased, a fact due in some measure to the resin-content of the raw rubber. The experiments were carried out with sheets 2 mm. thick, 5 cm. wide and 20 cm. long. Each sheet was tested in an apparatus which slowly bends the sheet until it breaks. The movement of the spindle is communicated to a pointer moving on a

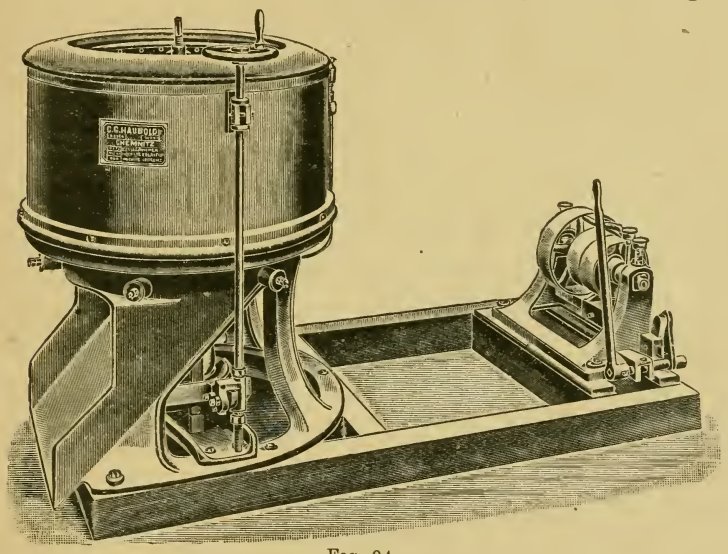


Fig. 94.

graduated dial. The figures obtained show the amount of bending at the breaking-point.

From the second table (p. 209) can be seen what influence certain quantities of sulphur and other ingredients have on the strength and structure of ebonite compounds made from different sorts of rubber.

Linseed oil, well boiled and free from water, or "white winter" (cotton seed) oil, is added with the object of improving the polish; on the other hand, by adding a higher percentage of oil and adjusting the amount of sulphur accordingly, that is to say, increasing it, substitute is formed.

In order to produce a horny cut or fracture, and to facilitate the further working up—turning, drilling, sawing—a certain amount of white wax is added to the rubber mixing.

To the cheaper qualities, especially for mechanical purposes, substitutes, asphaltum, pitch, and resins may be added, and in order to be able to make better use of moulds, magnesia usta.

Mixing is best done in separate stages, the sulphur and dust being first worked in, and the oil added slowly afterwards. When reclaimed rubber is used this should first be mixed with the raw rubber, and this holds good also for substitute. Care must be taken when mixing to avoid flaking, and the more finely the ingredients are worked in the cleaner will be the product. Lime should always be avoided, magnesia usta being used in preference where some such agent is necessary.

Kind of Rubber.	Sulphur, per cent.	Dust, per cent.	Vulcanisation in Water-bath, °C.	Relative Breaking Strain.	Fracture.
Para	20	...	½ hour, rising 8 hours at 135 1 hour ,, 140	5640	Smooth to jagged.
,,	23	...	8 hours ,, 135	5694	,, ,,
,,	35	...	6½ ,, ,, 140	6101	,, ,,
,,	30	...	6 ,, ,, 135	7848	Horn-like polish.
,,	20	10	7 ,, ,, 135	5713	Jagged.
,,	20	15	7 ,, ,, 135	5667	,,
,,	20	25	6 ,, ,, 135	6217	Smooth.
,,	25	10	6 ,, ,, 135	6618	,,
,,	25	15	5 ,, ,, 135	6213	,,
,,	25	25	5 ,, ,, 135	6022	,,
,,	30	10	5 ,, ,, 140	7486	Horny.
,,	30	15	4½ ,, ,, 140	7026	,,
,,	30	25	4 ,, ,, 140	5004	Hard.
,,	30	25	6 ,, ,, 140	4841	,,
,,	40	25	3½ ,, ,, 140	4109	Splintery, brittle.

The second stage in the manufacture consists in running the sheet, starting with the mixed rubber, which has been quite uniformly warmed up and kneaded. The sheet is, in most instances, doubled on the doubling calenders until it has reached a thickness when it can be dealt with on the doubling rolls, and it is then laid in sheet form on racks and kept ready to be further worked up. In running this sheet special care must be taken that no bubbles of air are included between the successive layers of the sheet, and that there are no markings on the surface, due to irregular passage through the rolls; if these defects exist in the calendered sheet the result is the formation of blisters, and irregular expansion and contraction of the sheet on curing. Once the sheets have been laid out on the cloth racks great care must be taken to protect them from dust and damp.

Ingredients added, per cent.	Para.	Columbia.	Lopori.	Upper Congo.	Madagascar.	Borneo.	Batanga.	Niggers.	Liberia.	Lagos.	
Sulphur . .	30	35	45	45	40	50	50	55	60	50	
	156	152	149	150	150	144	130	122	116	136	Extent of bending at fracture.
Sulphur . .	30	30	45	40	35	40	50	40	50	50	
Ebonite dust .	10	20	10	20	25	25	20	30	50	20	
	151	148	140	140	142	136	122	118	105	126	Extent of bending at fracture.
Sulphur . .	25	30	40	40	35	40	50	55	50	40	
Ebonite dust .	10	10	10	10	10	10	10	10	10	10	
Pumice . .	10	10	10	10	10	10	10	10	10	10	
	150	150	142	145	142	140	120	119	115	120	Extent of bending at fracture.
Sulphur . .	30	35	50	50	40	50	50	55	60	50	
Ebonite dust .	10	10	10	10	10	10	10	10	10	10	
Reclaimed. .	10	10	10	10	10	10	10	10	10	10	
	152	148	145	147	144	141	120	116	110	130	Extent of bending at fracture.

We have now to consider the third step in the manufacture of ebonite, namely, the making-up of the various articles, and as a matter of fact ebonite sheet is, in the case of many articles, the material with which the actual preparation of those articles begins. In the following paragraphs, therefore, the process of manufacture of such sheet is described in detail. The manufacture must be carried out in shops absolutely free from dust, shops on the upper floor being most suitable for the purpose.

In order to prepare ebonite sheet the following process, which is found to give good results in every way, is employed. The sheet in question is not rolled up from separate layers to the required thickness on a heated bench, but is doubled on the doubling calenders direct from sheet $\frac{1}{2}$ mm. thick, a compact sheet free from blisters

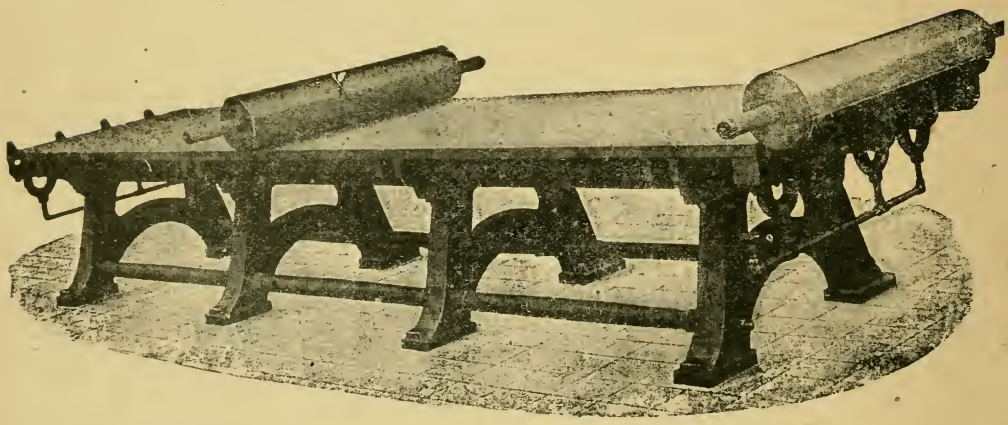


Fig. 95.

being thus produced. The sheet is then taken for further manipulation to the hot-bench, the ordinary form of which, shown in fig. 95, has long been in use. This hot-bench consists of a cast-iron plate, planed perfectly smooth and provided with interior channels for the purpose of heating it uniformly by means of steam. The chief use of the hot-plate is to warm up the rubber sheet so as to cause it to shrink, and prevent its shrinking during vulcanisation, and so to produce a uniform sheet. A second purpose served by the plate is, however, that of a bench on which the sheet is coated with tinfoil. This is done by means of a heavy iron roller worked by two men, the roller making the sheet uniform in thickness and homogeneous in texture, while at the same time forcing the air out from between the tinfoil and the rubber. By this means the tinfoil is hermetically sealed on to the rubber at the edges, and thus the polished surface of the foil is communicated

to the sheet of ebonite, and the surface of the sheet is kept from contact with water during the cure. Another advantage attending the use of tinfoil is that the polish obtained on the vulcanised sheet is very uniform and far superior in quality to any that could be obtained by polishing processes subsequent to vulcanisation. Well-trained hands are, however, necessary in order to successfully carry through this method of manufacture; the heavy rollers used are likely, in particular, to contribute a great deal towards mishaps and defective manufacture; their weight is sufficient, if they are moved unevenly or in a jerky fashion, or crookedly across the sheet, to produce a very uneven surface marked by wave-like depressions and elevations, and by pittings or concavities due to the pressure of imprisoned air. If the tinfoil is not put on evenly it will crease and form blisters, these giving rise in their turn to spots on the surface of the sheet, where the polish will vary in quality or degree. In order to surmount these difficulties, and at the same time to economise labour, a hot-plate has been constructed in which the roller is moved mechanically (system of Haubold and Heil). The manufacture in this case proceeds as follows:—The tinfoil in the form of a sheet twice the length of the rubber sheet to be covered, and folded in two, is lightly, evenly, and thinly coated with absolutely anhydrous linseed or solar oil on the side which is to come in contact with the sheet of rubber. The half-sheet as far as the fold is now laid on the hot-plate, and slowly covered with the sheet of rubber of the requisite thickness, by rolling the latter on to it; the sheet is then allowed to remain a few minutes for shrinking. The other half of the sheet of foil, beyond the fold, which is to cover the upper surface of the rubber sheet, is now laid smoothly over the roller in such a way that as the roller moves forward the tinfoil moves with it and is slowly laid on the sheet of rubber and firmly rolled down by the roller. The whole of this manipulation is carried out by the machine shown in fig. 96. The roller, about 300 mm. in diameter, is, as indicated in the diagram, moved forward and back again automatically, and is then automatically cut out. The two side-edges, which have to be closed up air-tight by the tinfoil, are pressed together by a small auxiliary roller, which can be adjusted to any width and thickness of sheet.

In this way a sheet absolutely uniform in surface and thickness can be prepared; it is safest to cure such sheets in the water-bath. The thickness of the sheet which can be made in this way varies from $\frac{3}{10}$ mm. to 15 mm. Thicker sheet should receive a preliminary vulcanisation under the press, as referred to below. In water-

bath vulcanisation the iron case in which the sheets are packed should be large enough for the water to circulate freely round the sheets. A thick cast-iron plate, planed smooth, serves as a base on which the separate sheets of foil-covered rubber of equal size are laid, care being always taken to avoid creases; it is not advisable to vulcanise more than fifteen to eighteen sheets each 3 mm. thick, in a single case. To prevent the sheets from being displaced, a cast-iron plate, planed smooth, and of the same size as the sheets, is laid on top of them. After vulcanisation—which, as stated at

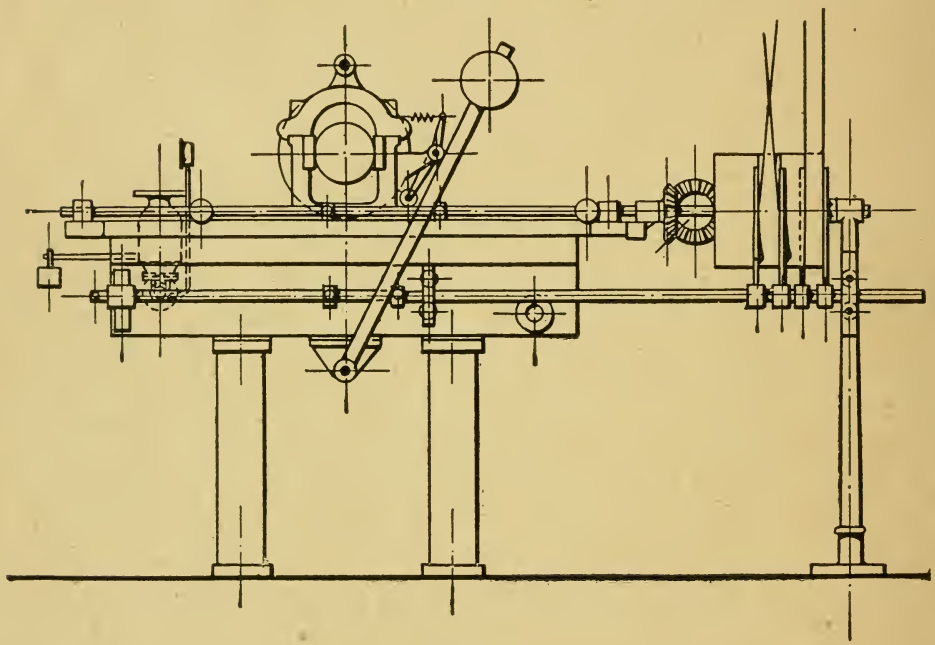


Fig. 96.

the outset, is regulated according to the quality and thickness of the sheet—the sheets are allowed to cool, and the tinfoil is then taken off and melted down again. In the process of doing this indications are obtained as to the correctness or otherwise of the vulcanisation. If the sheets are under-cured the tinfoil adheres tightly to them, and the sheets themselves are of a dull, dirty greenish-black colour, and leathery in texture; this mistake may be partly rectified by re-vulcanising the sheet. If, on the other hand, the sheets have been over-cured they are as hard as glass, and more often still are porous and carbonised.

Sheets more than 15 mm. thick are covered on the hot-bench with tinfoil; this is not, however, pressed down at the edges, but

cut with the sheet itself to the right size for the frame mould which is going to be used, and the sheet is then partly vulcanised in the press, under hydraulic pressure. The size of the frames used is determined by the thickness of the sheet, and the temperature at which the partial cure is effected is at first a low one, but is gradually raised until the sheet is about three-quarters cured. The cure of the sheets is then completed in the water-bath for from three to four hours, at a temperature not exceeding 130° C.; in this way the productive capacity of a plant is increased.

After vulcanisation the sheets are either worked up further, that is, cut up into other articles, for which purpose special saws are used, or they are sold as they are. In the latter case the sheet has still to be finely polished.

2. **Manufacture of Tinfoil.**—The consumption of tinfoil in a hard-rubber factory being exceedingly great, and since the foil can sometimes only be used once, its preparation is usually provided for in the factory itself. The foil is rolled from pure block tin.

The manufacturing process may be divided into three parts:—

1. Melting down and casting.
2. Preliminary drawing out.
3. Rolling and glazing.

The tin is melted down in a special oven, and the scale must be very carefully removed so that only a perfectly clean melt is poured; the metal should not be overheated. It is cast in iron Register moulds, 30 cm. square. Each mould is formed of a cast-iron plate in which a cavity has been planed out, surrounded by a rim 15 mm. thick. The back of one plate forms the cover of the next. On one side of each plate the rim is missing, the edge being slightly bevelled off. The plates are all built up together to form a mould. This is inclined at an angle of about 75°, the mould is closed by a clamp, and after it has been warmed up is ready for use. The casting is done in the ordinary way, the metal being slowly poured into the moulds from a ladle, while the moulds are cooled with water. The plates of metal obtained, which measure $300 \times 300 \times 15$ mm., are now drawn out on the mill illustrated in fig. 97, and are then rolled out on the tin-calenders,—which are similar in construction to the ordinary two-roll calenders (fig. 25), except that they must have rolls ground and case-hardened across their whole breadth,—to thin doubled foil of 120 cm.; soapy water is used as a lubricant. For comb manufacture the foil is calendered into narrow sheets about 15 metres long. This calendering process is carried out in several stages, the sheet of foil being

run thinner and thinner by gradually closing up the rolls, using soapy water as a lubricant. Finally, in order to improve the gloss and smoothness, the sheet is glazed and is then ready for use.

3. **Ebonite Rods and Tubes.**—The manufacture of these articles is in many respects distinct from that of sheet. Whereas sheet was covered with tinfoil and vulcanised in the water-bath, it was formerly the practice to vulcanise rods and tubing wrapped in cotton binders, the tubing being of course first placed on mandrels.

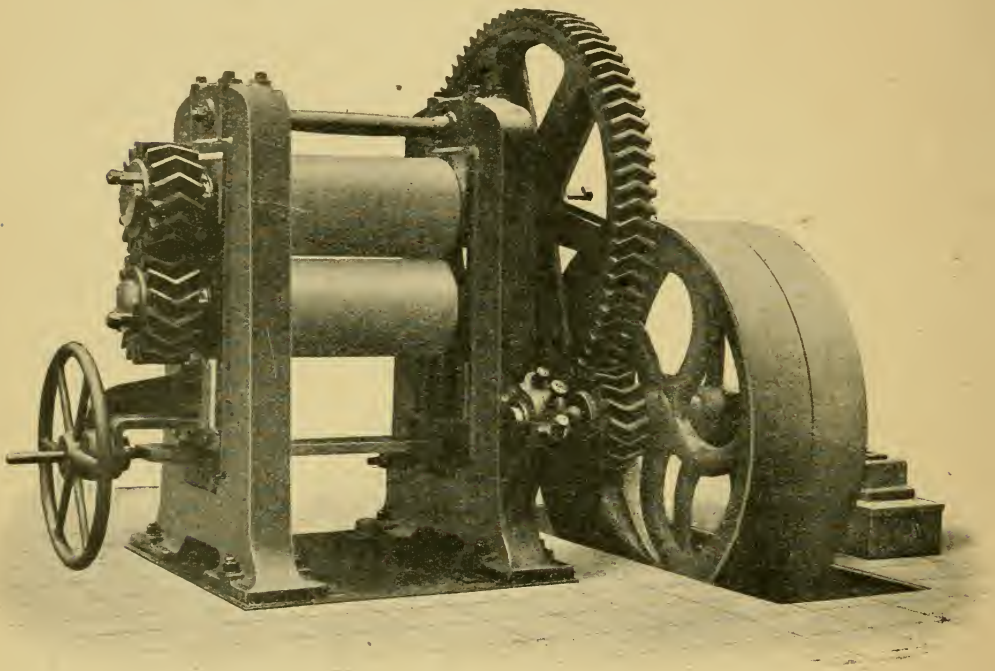


FIG. 97.

It is customary now to cure both these classes of goods in chalk in the open, or, as in cases where one is concerned with the production of an absolutely true and smooth-surfaced article, in glass or metal moulds, the inside walls of which are smooth. In carrying out this process care must be taken that both the moulding tubes and the machined ebonite cord or tube are evenly heated, so that the rubber may distribute itself evenly in the mould and fit closely against the walls. Some experience is, however, necessary here, in order to prevent air-markings on the outer surface of the rubber rod or tube. With the increasing use of magnesia usta this method of vulcanisation has come into more general use, the results obtained

being quite equal to those produced according to the older method. As a rule, the tube or rod is prepared on the tube machine already described, the particular article required being run to the desired dimensions. By working with the tube machine one obtains a much more uniform product, and the troublesome wrapping process is done away with. Moreover, no defects can arise in such tubing from faulty seams, whereas such defects are very likely to occur in the case of common, dry qualities with thin walls, made up by the wrapping method; on the machined rod, again, there is no seam-like marking showing where the edge of the rubber sheet came when the rod was rolled up. The mixings should be of such a composition that they do not tend to run out of shape during vulcanisation; they should therefore set rapidly, and this is generally ensured by the use of magnesia usta and ebonite dust as ingredients. The finest possible dust should be used so as to ensure getting very smooth surfaces straight away, and make subsequent burnishing unnecessary. Furthermore, the magnesia should be as free as possible from hydrate and carbonate, or porous goods may be obtained as a result of the evolution of gas on heating. In very highly polished tubes and rod the magnesia is omitted, the time of vulcanisation being correspondingly increased.

Tubing up to 15 mm. in diameter may also be vulcanised in the open without mandrels, according to the thickness of wall, whilst larger sizes for very accurate goods of smaller diameters, which must measure correctly to a hair's-breadth, are either run on the tube machine and then slipped on to mandrels, or run direct on to the latter in the proper machines, and vulcanised in moulding tubes. Rods more than 25 mm. in diameter after being run on the tube machine must be cured in tubes, and larger sizes still in moulds, since these larger sizes are very apt to swell and burst open. After being suitably vulcanised the rods and tubing are either further worked up, that is to say, turned, or they are regarded as finished products, in which case they are in part polished or burnished, processes which are dealt with later. Vulcanisation is carried out either in the water-bath or in hot-air chambers.

The rods and tubes made in this way are quite smooth and exact in dimensions.

4. **Insulation Tubes.**—Insulation tubes for electric conductors form one of the chief objects of attention in the tube machine department of an ebonite factory. The point to which greatest importance has to be attached is the production of a good insulator with as thin a wall as possible, and in this connection it is impor-

tant to put together the right mixing, so as to be able to make a tube which is tough without being excessively hard, and which can still be bent. The lengths of tubing should not be run from the tube machine on to trays, but in lengths of from 1 to 3 metres on to belt conveyors, passing through water, if necessary, as they leave the die of the machine, so as to cool them down rapidly and keep them in shape.

The following is a suitable mixing:—

Batanga	1,500 gms.	Sulphur	5,000 gms.
Balata	500 ,,	Brown rape oil substitute	8,000 ,,
Dust	6,000 ,,	China-clay (free from mica)	15,000 ,,
Almeidina	3,000 ,,	Whiting	6,000 ,,
Reclaimed	12,000 ,,	Palm- or castor-oil	2,000 ,,
Pontianac mixture	6,000 ,,	Magnesia usta	1,000 ,,
Talite, Atmido or Atmoid	15,000 ,,	Tar	2,500 ,,
Carbon-black	2,000 ,,		

Time of vulcanisation, about one hour at 145° C.

5. **Ebonite Accumulator Cases.**—The method of manufacture of these articles is not quite equal to the great demands put upon them, and very unpleasant consequences have frequently resulted from cases being badly made, or made from unsuitable mixings. Ebonite cases have to fulfil the following conditions, and should be made with this in view:—

1. They must withstand the action of sulphuric acid of 66° Baumé.
2. They should not soften at a temperature of 65° C., and must not be brittle at 10° C.
3. They must be reasonably tough to be able to withstand shocks without breaking.
4. They must be absolutely watertight.
5. They must not break down under a high-tension test at 30,000 volts.

The composition of the mixing will determine whether the first of these conditions is fulfilled or not. The following mixings are extensively used:—

A. Congo	10,000 gms.	B. Congo	10,000 gms.
Sulphur	4,000 ,,	Sulphur	4,000 ,,
Ebonite dust	2,500 ,,	Magnesia	250 ,,
Powdered pumice	5,000 ,,	Ebonite dust	4,000 ,,
Linseed oil	600 ,,	Powdered pumice	7,000 ,,
		Linseed oil	800 ,,

Pure silica, produced in the manufacture of sodium silicofluoride, may also be recommended as possessing advantages over pumice in this connection.

In order to produce a good serviceable case the course of

manufacture described below must be followed; attempts to economise by the use of light sheet-iron moulds instead of the heavier castings are doubtful policy. Cast-iron moulds should, without question, be chosen as the cores on which to make up, and as moulds on which to vulcanise, the cases, which vary in size from the smallest up to 70 cm. deep; the moulds should have a slight taper of about 1 mm. so that the finished cases can be easily taken off. The surface of the mould is brushed over with a thin solution of Para, in order that the rubber sheets may make intimate contact with it. The sheet of the requisite thickness is placed on the mould and rolled down with a rubber roller, starting from the top and working downwards. That portion of the sheet of rubber which projects beyond the corners of the mould is cut off square with the face of the mould by means of a thin sharp knife, and the adjacent surfaces are then applied. Finally, the bottom is placed on the mould, rolled down firmly and cut round the edges, and the case is now ready for vulcanisation. It is not necessary to enclose the case in an outer mould, since the surfaces are securely and firmly united, and the case cannot get out of shape on the solid mould. The case is vulcanised in chalk, the moulds being firmly embedded in it and covered with a good thick layer. Vulcanisation is complete in eight hours at 145° C. with the proportion of sulphur given above, and this composition and time of cure have been shown by a series of experiments to form an advantageous combination.

While the cases are still warm they are loosened from the mould in a small press, and are then taken right off and smoothed down by means of a sand-blast. By this means the faces are made quite even, and at the same time a considerable saving in wages is effected as compared with the process of buffing by means of emery-wheels; these are only employed to grind down the cases to the right height.

The cases should now be tested as follows:—

1. In a special apparatus under a water pressure of 1 atmosphere, to make sure that the seams are perfectly tight; and
2. as regards their behaviour towards high electric tension, the test being applied by means of a spark inductor.

The tested cases are varnished with an asphalt varnish, and are then ready for use.

6. **Moulded Ebonite Goods.**—A large proportion of the articles made in ebonite are vulcanised in moulds. The process is carried out in cases where metallic fabrics are pressed into the rubber, in

the same way as described for moulded soft-rubber goods. But, on the other hand, in order to economise in moulds and at the same time to produce smooth surfaces, certain articles may be given a preliminary pressing in steel moulds and the vulcanisation completed in hot-air ovens, or in compo-moulds which, amongst other things, may be dressed with collodion solution to prevent sticking to the mould. This process has found employment especially in the case of surgical goods; such articles as enema fittings, taps, screw-unions, cannulæ and cigar holders are made in this way, and it is not necessary to turn them up on the lathe

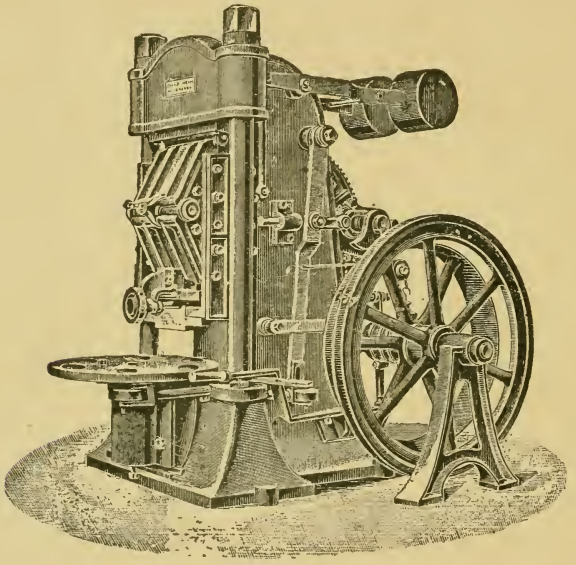


Fig. 98.

afterwards, since they come from the moulds with a perfectly smooth surface. All articles which are mounted on mandrels can be cured with comparative ease by means of hot air. Naturally they are not very smooth after vulcanisation, and have to be turned up before a polish can be put on. On the other hand, in the case of certain articles which are covered in tinfoil and vulcanised, or which are cured in moulds dressed with a special solution, a brilliant gloss can be produced, which gives the article a peculiar enamelled appearance, and does away with the necessity of subsequent polishing. Combs are made in the same way. The sheet rubber is pressed into the comb moulds, between sheets of tinfoil, by means of heavy bent-lever presses (fig. 98), so as to form a flat piece of the shape of the comb, but without the teeth.

The teeth are cut out after vulcanisation by means of automatic saws, the ingeniously-constructed machine working in such a way that the slot in which the comb is fixed, according to the number of teeth, moves towards the revolving saw, and is automatically thrown out as soon as all the teeth of the comb are cut; the comb has then only to receive the final polish. By a special arrangement of the mould the teeth can also be first of all pressed out.

7. **Buffing and Polishing Ebonite.**—The buffing of ebonite sheet

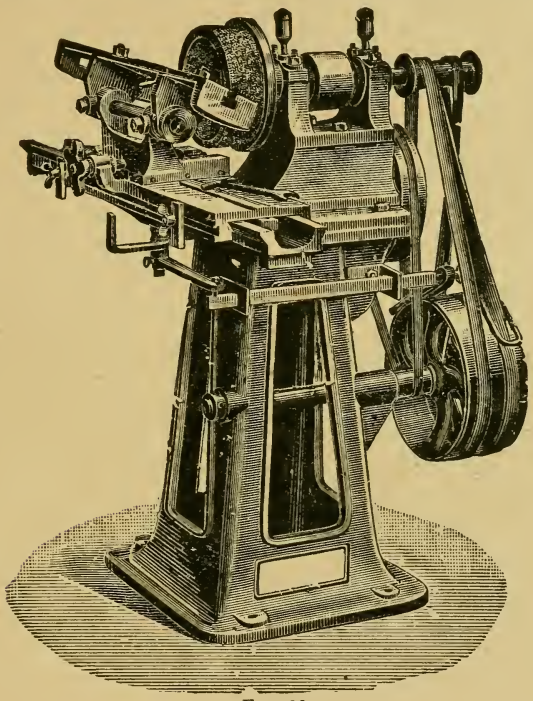


Fig. 99.

and surfaces of other ebonite goods must be done in a continuous stream of cooling water, and the articles being buffed should be pressed as lightly as possible on to the buffing wheel, in order that the ebonite may not become too strongly heated. For sheet ebonite an automatic buffing machine is used, in which emery-wheels are moved evenly over the whole surface, rubbing down the sheet, which is immersed in water, with fine Tripoli or pumice powder. No cracks or streaks should show themselves; if they do, the sheet should be at once cooled down. In fig. 99 is illustrated a special machine for buffing ebonite. Smaller articles are either tubbed, or buffed with powdered pumice on emery buffs or maize-

leaf wheels working wet. After buffing, the articles are scrubbed with brushes in order to remove all the fine Tripoli dust or pumice powder still adhering to them, before being oiled, dried, and polished. If the article should remain dull in appearance it is rubbed down with a little linseed oil; on the other hand, in order to produce a polish the ebonite must be worked on rapidly revolving flannel buffs with fine Tripoli powder and a little linseed oil until a deep gloss is produced. In carrying out this operation the ebonite should not be rubbed too hard, or it will become overheated and lose its capability of taking a polish.

Should spots and greenish-coloured patches show themselves on the surface—defects which are due to the action of moisture during the process of vulcanisation—they may be easily removed by repeatedly rubbing them over with carbon disulphide.

8. **Ebonite "Mechanicals."**—Amongst the most important of these goods are the coverings for the machinery and boilers used in chemical works; they constitute a branch of ebonite manufacture which demands much experience and knowledge; the difficulties are increased by the circumstance that the articles have to be made without moulds. In covering heaters (Montejus) the following are the points most worthy of note:—The surface to be covered must be roughened as thoroughly as possible, after which it is carefully warmed up and cleaned, and then dressed with a suitable solution. When this is dry a layer of unvulcanised ebonite is rolled down on to the iron; this layer of ebonite must fulfil the following conditions:—

1. It must make good contact with the iron.

2. It must be tough and as hard as possible without being too brittle.

3. It must not contract to a greater degree than the iron, or it may break away from it.

On the top of this layer a suitable hard quality is rolled down; this also should show very little contraction; finally, the actual insulating quality is put on, and this must be absolutely stable towards acids. If a partition is to be made in the heater only such a quality can be used for it as shrinks very little, and this may, with advantage, be partly vulcanised first of all by itself.

When covered, the heater is allowed to stand for some time, in order that any blisters which make their appearance may be pricked or pressed out. The inside of the heater is filled with chalk, tightly packed, and vulcanisation is then carried out at 130° C. with a gradual rise. Coverings for centrifugal machines are put on in

exactly the same way. The small holes which have to be covered round, are filled with tubing of the right outside diameter, through the inside of which passes a short nickel rod of the diameter of the finished hole. The whole centrifugal basket is packed in chalk and cured. Vulcanisation may take anything up to fifteen hours at 135° C. according to the size of the basket. The chalk should only be removed when the article has slowly cooled down. Taps, curves, bends, and shaped pieces, of different inside measurements, can be most conveniently dealt with on thin, stiffened, hollow, sheet zinc cores; it is important to see that the individual parts will all cure in the same length of time, for one cannot cure pieces of over 30 cm. in diameter with a wall 8–10 cm. thick, of one quality. They would be porous in the centre, and would blow, and cause the article to burst. In order to remove the zinc core it may be dissolved away in hydrochloric acid. By this means a much better mould can be produced inside than if a corresponding plaster mould were used. Plaster cores are, on the one hand, difficult to remove, and, on the other hand, produce a very rough inside surface.

Quite recently it has become the practice to insulate ship's screws and their bearings with ebonite, in order to stop the corrosion due to local currents, which have been known to eat out even 25 per cent. nickel steel from the propeller shaft. Traun's protected process for covering propellers, used on ships of the German Navy, may here be referred to. These qualities should be perfectly homogeneous and durable, and, on the other hand, should adhere firmly to the steel. Vulcanisation is carried out, in heaters of their own construction, by means of hot air, in the docks, in order to save the very considerable costs of transport.

9. **Imitation Ebonite.**—The various resinous compositions put on the market under different names can be quite advantageously used for the preparation of solid articles, used for insulating purposes in the electrical industry, for surrounding and insulating all kinds of metal parts, which are made in large quantities.

The insulating material occurring in commerce under the names "Ambroin," "Ebolite," etc., consists of an intimate mixture of resins, fibre, and fillers, and is prepared by the method explained below.

The basis of the composition is resin. Lac resin (*resina lacca*) or shellac is used by preference. Gum-lac comes from the branches of several trees and shrubs, such as *Ficus religiosa*, L.; *Ficus bengalensis*, *Ficus indica*, *Butea frondosa*, Rb.; *Croton aromaticus*, *Croton lacciferum*, L.; *Ziziphus Jujuba*, Lam. The first-named of these is a strong East Indian tree of considerable size, with pointed,

oval, somewhat heart-shaped leaves. The "fruits" are rounded and elongated, and are actually none other than the enlarged receptacles, to the inner walls of which the extremely small flowers and fruits proper are attached. Gum-lac results from the perforations made by a species of coccus, *Coccus lacca*, in the young branches of the tree. These insects, with their brood, become surrounded by the glutinous liquid which exudes,[1] later on boring their way out through the outer shell, leaving behind the mass of resin still adhering to the branches; this is collected with the fragments of wood attached to it, and is called stick-lac. The pieces are taken off the branches, and when freed from pigmenting material by treatment with sodium carbonate, are known as button-lac. This button-lac is heated, forced through linen bags, and pressed between Pisang leaves into sheets of varying degrees of thinness; this forms true shellac. It is a yellowish-brown to brownish-red, hard, glossy, transparent substance, which clings together in large pieces. Shellac is an article of commerce in Bengal, Assam, Siam, Annam, Sumatra, and China; that which comes from Bengal is, however, accounted the least valuable.

The more transparent a shellac, the greater is its value. Shellac is only partially soluble in cold alcohol, leaving undissolved a sticky mass, the so-called "wax."

The other resin used in the preparation of imitation ebonite is copal (*resina copal*).

There are various kinds of copal on the market, the chief sorts being the following:—West Indian copal, obtained from *Amyris copallifera*, Sprengel, a member of the Terebinthaceæ. In October and November the resin exudes from the bark of the trees in drops, and is collected and melted together. The fracture is highly vitreous, the colour varying from light to dark.

Brazilian copal is derived chiefly from *Hymenæa Courbaril*, Linn., and is of two kinds. The first kind oozes out of the bark and forms tear-shaped, somewhat angular pieces of a yellowish to yellowish-red colour, transparent, with a vitreous fracture; while the other kind is found in the earth beneath the roots, and forms egg-sized lumps, with a wrinkled surface.

Copal being cheaper than shellac, it is of advantage to use the former in the preparation of imitation ebonite. Proceeding now to the actual manufacture of the mass, the following details should be noted.

The resin is dissolved in solution mills (Pfleiderer's system), in

[1] The now generally accepted statement of the case is that the lac is mainly, if not entirely, a secretionary product of the coccus, elaborated by it from the sap of the tree.—See Tschirch, *Die Harze und Harzbehälter*, 1906, pp. 812, 813.

125 per cent. of its own weight of absolute alcohol; the process of solution is completed more rapidly if the resin be first of all powdered in an Excelsior mill. The liquid is filtered, and the residue on the filter is warmed up and treated with a further quantity of solvent, this solution being afterwards added to the main portion. In addition to the resin, the mass contains asbestos fibre, jute fibre, and the various fillers, such as china-clay, magnesium carbonate, zinc oxide, barytes, and lithopone. The colouring matters used are Frankfort black, nigrosin, carbon-black, the last-named only in small quantity, since it is a good conductor, and iron oxide or *caput mortuum*. The various materials are weighed off and put into a large Pfleiderer machine; the latter is set in motion and the resin solution slowly added, the extra spirit necessary being added later. When the mass has been worked up for about an hour, and the ingredients are intimately mixed together, the asbestos and jute fibre, which must be thoroughly disintegrated, are scattered in gradually in the form of a very light fluff. It may here be noted that the asbestos fibre should be teased out as thoroughly as possible on the fur carder; the finer the fluff, the better the properties of the finished mass. The mixing-machine must be kept going for one and a half to two hours longer, until the dough is ready for use. The latter is then spread out on sheet-iron racks to a depth of 2 cm. and put into the vacuum drier. The alcohol is distilled off and recovered for further use. The drying is completed at 140° C. with a vacuum of 65 cm. in about 2½ hours.

In order to work up the mass still further, it is crushed on the "Kaiser" mill (fig. 92), and finally ground in the Excelsior mill. The powder thus obtained is compressed in moulds and made into articles of various shapes.

The following mixings may be recommended as suitable for different purposes:—

	gms.	gms.	
Resin solution	30,000	12,500	
Alcohol	8,000	3,000	
Ambroin waste (powdered)	15,000	2,500	
China-clay	5,000	1,500	
Magnesia	10,000	3,000	
Talite or atmoid	5,000	1,000	
Frankfort black	4,500	1,750	Iron oxide or
or Nigrosin	500	250	fuchsin
Asbestos fibre	5,000	4,000	
,, ,, waste	2,500	1,250	
Jute fibre	2,250	800	
Linseed oil	750	550	
Ozokerite	250	200	
Burgundy pitch	7,000	750	
Colophony	2 000	...	

For glossy imitation ebonite:—

Resin solution . .	12,000 gms.	Zinc white . . .	2,000 gms.
Alcohol . . .	3,000 ,,	Carbon black . .	750 ,,
Magnesia . . .	1,200 ,,	Asbestos fibre, fine, short . . .	5,000 ,,
China clay . . .	2,500 ,,		

10. **Moulding and Pressing Imitation Ebonite Goods.**—Every article is made by compression in steel moulds, made up in three portions:—

1. The outer casing.
2. The matrix or mould proper.
3. The plunger.

The outer casing encloses the matrix, and must be designed with very thick walls. It is also designed, as far as practicable, to take as many different moulds as possible, so that the one casing will serve for all moulds of a similar type. The plunger serves to compress the mass, and should be an exact fit to the matrix.

The method of procedure is as follows:—

The powdered mass already described is accurately weighed out, filled into the mould, and compressed by means of the plunger under small hydraulic presses at a pressure varying from 75 to 300 atmospheres. The moulds are put into hot-air ovens for about ten minutes, then slightly cooled, and the matrix and plunger forced out of the jacket in the same way as they were put in, when the finished article drops out of the matrix. The manufacture can be carried through very rapidly, and an experienced hand can mould as many as 400 pieces of simple construction—*e.g.*, handles—per day.

The final process consists in buffing on emery-wheels and varnishing.

Imitation ebonite which is to have a good polish after coming from the press must, on the other hand, remain for about ten minutes under the press at 75 atmospheres pressure.

Naturally the material cannot be worked, drilled, or turned very well, since it breaks very easily, but where moulding is possible it constitutes a cheap electric insulating material, with a high resistance amounting to as much as 80,000 megohms, and can easily be applied to the insulation of metal parts of the most varied shapes.

APPENDIX I.

THE REGENERATION OR RECLAIMING OF RUBBER WASTE AS CARRIED OUT IN RUBBER GOODS FACTORIES.

Nearly all waste rubber is used over again in some form or other. The factories which have been established for the express purpose of reclaiming waste rubber have latterly advanced beyond the stage when old rubber shoes constituted the chief form of rubber waste worked up by them, although such old shoes are the basis of a very considerable proportion of the reclaimed rubber used in rubber factories. But, except in a few instances, the reclaiming of old rubber shoes is not, as a rule, carried out in the rubber factory, but in special factories. This statement holds good, also, for old bicycle tyres. The typical reclaimed rubber factories of Theilgaard in Copenhagen have been already so clearly described in the *Gummi-Zeitung*[1] that it is only necessary here to refer the reader acquainted with German to the articles in question.

The following short account is therefore concerned only with the reclaiming process as carried out in the rubber factory itself.

The fact that by no one of the reclaiming processes at present in use is it possible from vulcanised waste to reproduce *unvulcanised* (*de*vulcanised) rubber, must be assumed to be well known. The sole result of reclaiming processes as now applied is to render the rubber plastic again. If in any given instance the vulcanisation coefficient is reduced as a result of the reclaiming process, the reduction is only slight, and indicates that the rubber substance has undergone some decomposition. The only case in which this is not absolutely true is that of cut-sheet (or other cold-cured) waste, but the reduction is in this case due to the removal from combination with the rubber, not of sulphur, but of chlorine, a result which is achieved with comparative ease by heating the waste with solutions of the alkalis or alkaline earths.

[1] 1904, xix. pp. 87–93.

Practically the only really important operation in the whole process of working up rubber waste is the sorting of the waste. By carrying this out in a rational way the subsequent processes can be very much simplified.

Cut-sheet waste may be first of all referred to. This kind of waste is generally reclaimed by heating with alkali; the alkaline solution attacks the chlorine of the rubber, and to a still greater extent the white substitute. It is not possible to prevent the waste in question from becoming more or less dark in colour as the result of the heating and subsequent plasticising process (during which process the caustic liquor is, of course, washed out of the rubber), and as a rule, therefore, the uncoloured waste is not treated separately from the black; indeed in many factories the red waste is also included with these. As a result of such treatment with caustic soda, and subsequent heating in steam at a pressure of about 5 to 8 atmospheres in order to render it plastic, cut-sheet waste yields a product which can be more or less used in the place of raw rubber in a number of mixings. The vulcanisation coefficient of such a product is very low, and there is, therefore, room for a considerable degree of after-vulcanisation. This product, however, often smells very unpleasantly of the decomposition products of the white substitute. Its use in red goods which contain golden sulphide is not to be recommended.

Floating waste is either uncoloured (grey), red, or black, for a good white which floats cannot be produced on account of the high specific gravity of the white pigments [or, rather, on account of the large proportions of such pigments required to mask the natural colour of the vulcanised rubber]. Floating waste is, therefore, sorted into "grey," "red," and "black." The sorted waste is generally heated with oil after being finely ground on roller mills with three rolls (fig. 100), which are also in part fluted. By this means a highly plastic mass of great stickiness is produced, which imparts to mixings in which it is employed a very great power of absorbing mineral compounds. Red floating waste should be specially examined to see that it contains no cold-cured waste, so that the golden sulphide may not change colour on reclaiming. To reclaim red floating bottle-washers it is only necessary to heat them under suitable conditions. Heating with oil is generally conducted in jacketed heaters, and the waste is kept well agitated during the process. Bottle-washers, on the other hand, are heated in the ordinary vulcanising heaters in steam at a pressure of 11 to 12 atmospheres. The heated bottle-washer waste must, of course, be

afterwards dried in the vacuum drier before being run out into sheet. That floating bottle-washers can be plasticised without the addition of any oil is due to the fact that the so-called "Para-factis," which is used in considerable proportions in bottle-ring mixings, usually contains about 45 per cent. of acetone-soluble oily and waxy constituents. With between 30 and 45 per cent. of this substitute in the mixing there is, therefore, present in the waste between 14 and 20 per cent. of oils and wax, which is ample to plasticise it, for the amount of rubber present is only between 48 and 63 per cent.

In non-floating waste a distinction is made between that which

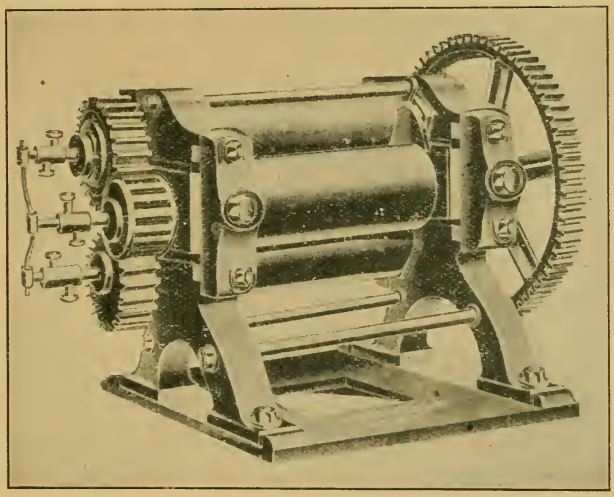


Fig. 100.

contains fabric and that which does not. Both kinds of waste, again, are sorted according to colour. Drab waste, and frequently also red, generally contains considerable quantities of free sulphur. For this reason this kind of waste is often desulphurised before it is heated with oil, by grinding it into fine crumb and then boiling it up with a solution of caustic soda or of sodium sulphite. The waste is then thoroughly washed and heated with about 20 per cent. of its weight of rosin oil, castor oil, or palm oil, occasionally also with paraffin wax. In a few factories this heating process is carried out under vulcanising presses, but most works probably employ for the purpose the jacketed heater with agitator.

The treatment of waste containing fabric insertions formerly gave rise to all kinds of difficulties in removing the insertion. Only

in the case of dark waste could acids be used to destroy the fibrous material. The acid treatment, too, was accompanied by a number of drawbacks, such as evolution of sulphuretted hydrogen, decomposition of whiting and other fillers, with formation of gypsum, etc., so that an important step forward was taken when other methods of destroying the fabric were introduced. One is now enabled by the use of these methods to reclaim both white and red waste containing insertion.

It is usual to free the plasticised waste, either on the refining roller mill or on a tube machine provided with a fine sieve, from all coarse particles that may still be present.

The possibility of reclaiming certain kinds of black waste, either without any addition, or by adding very small quantities of oil, etc., depends upon the presence in such waste of quite considerable quantities of pitch. In rubber shoes the resinous and oily substances of the varnish are present in addition to the pitch. Proofed, uncured canvas waste is sometimes ground up into fibre and then added to the mixing direct, or else the unvulcanised rubber is recovered in an extraction apparatus, with the object of using it again for solution.

It must, of course, be admitted that the regeneration of rubber on the works itself is always less satisfactory as regards the product turned out than the recovered rubber produced by factories which make reclaiming a special business. For one thing, the price of old rubber is very much inflated by an extensive demand on the part of a large number of works, much more so than if the whole were being purchased by just a few large reclaiming works; and it is further obvious that the sorting and blending of the waste can be done to a much greater nicety when dealing with the large quantities used in a reclaiming works, than when, as in the case of a rubber factory reclaiming waste for its own use, one has to deal only with comparatively small quantities of material. Moreover, the cost of reclaiming is naturally higher in a rubber works than it is in a special factory. For these reasons the practice of reclaiming in rubber factories is gradually being given up.

[A process which seems likely to prove of considerable value in a number of cases, is that described under Gare's English patent No. 12,454, 1906. In this process the two following well-known facts find practical application, viz. (1) that when heated in contact with air, vulcanised waste is decomposed; (2) that when heated out of contact with air such waste is softened. According to the process the waste rubber is finely ground, and is then highly compressed

in moulds in order to drive out all air from between the fragments of waste. The mould, still under pressure, is then heated at about 205° C. for a length of time depending on the size of the mould, and is then allowed to cool before being opened. Under this treatment the waste amalgamates and forms an extremely dense mass, possessing good properties, and taking the shape of the mould accurately. Such articles as buffers, cab tyres, etc., are those to which the process is best adapted.]

APPENDIX II.

SPECIFIC GRAVITY.

Specific gravity plays a considerable part in the rubber trade, not so much in estimating the quality of a given sample of rubber, as in ascertaining whether, for example, two samples of rubber from different sources will yield the same length per lb. of gas tubing, etc., of a given size, or, in the case of such goods as are bought by weight and sold again by size or by the article, the same number of articles. The dealer in rubber goods knows far too much nowadays to regard specific gravity as a criterion of quality.

Specific gravity is a relative number; it shows how many times heavier or lighter a given article is than the volume of water at 4° C. which it displaces. Hence the article in question should, strictly speaking, be weighed at a temperature of 15° C. and the result calculated, by the aid of factors, to water at 4° C. It is not usual to employ so accurate a method of specific gravity determination in the rubber trade. The article in question is simply weighed in distilled water at 15° C., and the value found is subtracted from the weight of the article in air. The latter value is then divided by the difference between the two weights, and it is customary to call this quotient the specific gravity; it serves generally as a basis for the calculations of seller and buyer. Articles which float in water must either be weighed in some liquid which is lighter than water, or be attached to a glass sinker and then weighed in water. If the unknown quotient be called x, the weight of rubber y, the loss in weight of rubber + glass when immersed in water z, and the loss in weight of the glass alone in water u, the specific gravity can be readily calculated from the following formula:

$$x = \frac{y}{z-u}.$$

For practical methods of carrying out the determination, reference may be had to the very useful little book by Marzoll, *Anleitung zur Gewichtberechnung technischer Gummiwaren, sowie zur Ermittelung der specifischen Zahlen,* Dresden, 1904.

The method of determining the specific gravity of rubber goods by weighing in air and in water is so simple, and capable of being carried out so quickly, that there would appear to be no object in attempting to simplify it still further, whether by having a number of standard solutions ready made up to definite specific gravities, so that the pieces of rubber may be dropped into each in turn until in one of them it is found to just float (a method which is not so simple in practice, on account of the great difficulty of keeping the standard solutions accurate, and the necessity for cleansing and drying the sample after immersion in one solution before it is put into the next), or by adopting Minikes' modification of the floating method. This consists in dropping the sample of rubber into a test-tube graduated on two opposite sides and containing a solution of zinc chloride (of sp. gr. 2·000), diluting the solution until the rubber just floats in it, and then reading off the specific gravity from the graduations. The particular rubber article being examined is often too large to be put into the Minikes test-tube, and must not be cut.

Since, therefore, all determinations of specific gravity can be carried out on a good Mohr-Westphal balance, a Reimann's sinker is provided with the balance, so that where necessary the weighings can be carried out in media other than water, and the specific gravity determined by means of the sinker-thermometer which has 5 c.c. displacement. A good method of dealing with floating rubber goods is to weigh them in alcohol or in similar liquids of specific gravity less than 1·000.

INDEX.

Absorptive power of reclaimed rubber, 226.
Accumulators, hydraulic, 75.
Accumulator cases, 216.
Acid-resisting rubber, 104.
African rubber, 14, 15, 17, 18, 19.
Air, compressed, 129, 139.
Air-cushions, 155.
Air, hot, 85.
Air-markings, 136, 152.
Albuminoids of rubber, 17.
Alkali nitrites, 137.
  solution, caustic, 225.
Aluminium bronzes, 90.
Ambroin, 221.
American rubber, 6–19.
Ammonium carbonate, 136.
  nitrite, 137.
Analysis of rubber, 17.
Analytical values, 19.
Arrangement of a rubber factory, 1.
Asbestos fibre, 191, 223.
  sheet, 192.
Asiatic rubber, 16.
Asphaltum in mixings, 116.
Asphalt varnish, 217.

Balls, 136.
  mixings for, 137.
  painting, 139.
  vulcanising press for, 138.
Ball valve, 135.
Band saws, 144.
Bands, elastic, 158.
Beaded edge of tyre, 152.
Beaming machine, 130.
Behaviour of rubbers on mixing rolls, 41.
Belting, 145.
  calenders, 146.
  vulcanisation of, 14.
Belt-folding machine, 145.
Bent-lever press, 218.
Benzine, 162, 164.
Benzole, 82, 162.
Besk, 19, 115.
Bicycle tyres, 150.
Billiard-strip, 135.
Blisters in hose, 131.
Blocks for "cut-sheet," 174.
Blooming, 63.
Boilers, 3.
Bolivian Para, 7.
Bottle-washer waste, 226.
Braided hose, 125.
Braiding machine, 126.
Brake rubbers, 150, 154.
Brass mandrels, 129.
Bronze-colour printing, 89.

Cable-coating machine, 188.
Cable, insulated, 188.
  insulation, 190.
Cables, electric, 188.
Cab-tyres, 135.
Calabashes, 8.
Calendered sheet, 197.
Calendering sheet-rubber, 47, 54, 155, 208.
Calenders, 46, 197.
Calotropis gigantea, 16.
Cameta, 10.
Canvas hose, 129.
  lining, 130, 141.
Caps of galoshes, 182.
Carbon bisulphide, 82.
  black, 178.
  dioxide, 137.
  tetrachloride, 82.
Carding machine, 223.
Castilloa elastica, 13.
Casting tin, 213.
Caucho, 12.
Caustic soda solution, 227.
Ceara rubber, 11.
Centrifugal machine, 34, 38, 206.
  covering with ebonite, 220.
Celluloid spreading-knife, 126.
Ceylon Para, 11, 17.
Chalking apparatus, 121, 140.
  machine, 170.
Chemical properties of rubber, 19.
  valuation of rubber, 17.
Chloride of sulphur, 59.
    action of, 80.
  of zinc, 229.
Chlorine content of reclaimed rubber, 225.
Coal-tar addition, 116.
  colours, 88.

Coating cable, 188.
machine, 188.
Cold vulcanisation, 80.
Collection of "Para," 7.
Collodion solution, 218.
Coloration of rubber, 20, 103.
Coloured effects on waterproof, 88.
Combs, manufacture of, 218.
Compresser, 175.
Condenser, 175.
Cone drive, 175.
Contraction of rubber, 101, 145, 152.
Control, analytical, 104.
Conveying bands, 184.
Cooling capacity, 175.
Copal, 222.
Copper, action on rubber, 90.
Cord, 139, 145.
Couplings, 31.
Cryptostegia grandiflora, 16.
Cut-sheet, 173.
manufacture, 173.
thicknesses of, 177.
waste, 225.
Cutting-out machine for galoshes, 180.
"Cyclone," 206.

Dead Borneo, 19, 115.
Deckle straps, 135.
Decomposition products, 82, 226.
Depolymerisation, 20, 39, 41.
Designs in relief on waterproof, 168.
Dew-formation on cold-cured goods, 82, 90.
Diathermancy (of ebonite), 202.
Dies of tube machine, 139.
Dipping bench, 98.
Discharging electricity from proofed sheet, 93.
Distillation (destructive) of rubber, 21.
Dolls, rubber, 137.
Doubled waterproof fabrics, 84.
Doubling calenders, 84, 87.
rollers, 55.
Draw-plate, 76.
Drum-moulds for tyres, 152.
Drying-plant, 36.
Drying washed rubber, 34.
"Dryness" of mixings, 116.
Dyestuffs, 88.

Ebolite, 221.
Ebonite, covering articles with, 220.
dust, air-separation of, 206.
centrifugalising, 206.
expansion of, 202.
imitation, 221.
manufacture, 201.
mixings, 206.
moulded goods, 217.
rods and tubes, 214.
sheet, 208.
waste, 203.
Elasticity, 196.
Embossing calenders, 171.
Enamelling, 156.
Engine-room, 3.
English hose, 125.
Engraved roller, 171.
Eraser rubber, 195.
Estrada, 8.
Evaporation pipes, 175.

Felted asbestos, 191.
Feuille anglaise, 177.
Ficus elastica, 16.
plantations, 16.
Figure-eight cut, 135.
Fillers, 104.
Filter flannel, 206.
press, 156.
Flower-tubing, 141.
Foglia segata, 177.
Forcing apparatus for removing hose from mandrels, 129.
Freezing-chamber, 174.
plant, 174.
Frictioning, 57.
Frictions, 101.
Funtumia, 14.

Galoshes, 177.
Gas-bags, 155.
Golden sulphide, 109.
Grease rubber, 196.
Grinding rolls, 205, 206.
waste rubber, 226.
Grooved rolls, 145.
wheels, 189.
Guayule, 14, 62.
Gutta Jelutong, 19, 115.

Hancornia speciosa, 12.
Heating tank, 23, 27.
Heel-pieces, 182, 183.
Herb-rubber, 14.
Hevea brazilensis, 6, 12, 41.
latex, 7.
High-pressure hose, 125.
High-tension cable, 190.
Hollander, 26, 29.
Hollow articles, 134.
needle, 139.
Hose, 120.
outer coat, 123.
inner coat, 128.
lining, 130.
shop, 5.
Hot-air chambers, 85, 187.
heater, 85.
vulcanisation, 85.
bench, 210, 211.
water bottles, 155.
Hydraulic autoclave press, 135, 153.
pressure, 147, 174.
Hydrocellulose, 193.
Hydrochloric acid formation in cold cure, 91.

Imitation leather cloth, 171.
Ingredients of mixings, 104.
Inner coating of hose, 128.

Inner soles, 182.
tubes, 150.
Insertions, 122.
Insides of galoshes, 182.
Instantaneous release, 45.
Instep pieces, 179, 182.
Insulating power, 191.
Insulation (electrical), 104, 188.
resistance, 191, 224.
tubes, 215.
"Ite" compositions, 192.

"Kaiser" mill, 204, 223.
Kickxia, 14.
Knife for "cut-sheet" work, 175.

Lake pigments, 88.
Landolphia, 14.
Lasts for galoshes, 178.
Latex, yield of, 8.
Leuconotis eugenifolius, 16.
Linseed oil, 206, 211.
varnish, 186.
Litharge, 63, 101.
Lithopone, 104.
Loom, 130.

Madagascar rubber, 15.
Magnesia usta, 63, 102, 214.
addition to mixings, 103, 141, 208.
Making-up galoshes, 184.
Mandrels, 121.
Mangabeira, 12.
Manhole washers, 144.
Manihot glaziovii, 11, 41.
Manometer, 67.
Maple wood, 178.
Masticators, 174.
Mattogrosso Para, 10.
Melting-point of rubber-sulphur mixture, 62.
Melting tin, 203.
Metallic sulphides, 60.
Micranda siphonoides, 7, 41.
Microporosity, 137.
Mixing, 40, 41.
ebonite, 208.
rolls, 40, 44.
with cylindrical sieve, 45.
room, 42.
Mixings, various, 105–109.
for accumulator cases, 216.
balls, 137.
belting, 147.
cushions, 155.
dolls, 139.
ebonite, 206.
insulation tubes, 216.
enamels, 156.
elastic bands, 158.
imitation ebonite, 223.
inner tubes, 150.
rollers, 150.
rubber stamps, 161.
shoes, 181, 182, 184.
Mixings for shoe-linings, 184.
vulcanised asbestos, 191.
Moisture in insertions, 131.
Mono-rubber, 19.
Motor tyres, 152.
Moulding, 134.
ebonite goods, 217.
Moulds for imitation ebonite work, 224.
Murupita, 7.

Negroheads, 9,
Nitrites, alkali, 137.
Nitrogen, 137.

Odour of cold-cured goods, 91.
Oil, addition to mixings, 103, 117.
Oil-resisting qualities, 105.
Ornamentation of waterproof, 86.
Outer-covers (of tyres), 152.
Oxidation of crude rubber, 23, 35.
vulcanised rubber, 22.
Ozokerite, 137.

Packing sheet, 141.
Paper rollers, 147.
Para, 6, 100, 203.
entrefine, 8.
hard and soft cure, 9.
plantation, 11.
sheet, 196.
Paraffin wax, addition of, 103, 117, 140.
Pedal-rubber punch, 155.
Perambulator tyres, 155.
Peripheral speed, 189.
Peruvian ball, 12.
Petroleum, 118.
Physical properties of rubber, 19.
Pigments, colouring rubber with, 88.
Pitch, 103, 116, 137, 190.
Plan of rubber factory, 1.
Plaster matrix, 159.
Plasticising, 225.
Plasticity of rubber, 20.
Pneumatic tyres, 150.
Polishing ebonite, 219.
Polish of ebonite, 218.
Polymerisation, 18.
Pontianac, 19, 115.
Porosity, 190.
Preliminary working of rubber, 40.
Press-cured sheet, 145.
Press-shop, 71.
Pressure equilibrium (in heaters), 85.
gauge, 67.
hose, 120, 128.
Printing cloth, 169.
Proofing, 162.
in colours, 165.
on calenders, 170.
Propeller-shaft, 221.
Proteins of rubber, 17.
Pumice, 216, 219.
Pump valves, 145.
Purification of crude rubber, 23.
Pyramidal impression, 179.

Radifix, 196.
Raw rubber, 6.
Reclaimed rubber, absorptive power of, 226.
Refining rolls, 227.
Refractive index of ebonite, 202.
Refrigerator, 174.
Regeneration, 225.
Resin-content, 12, 17, 179.
Revolving sieve, 43, 45.
Roller-adjustment on calenders, 48.
Roller buffing machine, 149.
  cores, 147.
Rolls for manufacture of "ite" sheet, 193.
Root rubber, 14.
Rosin oil, 118.
Rubber, African, 14, 15, 17, 18, 19.
  American, 6–19.
  Asiatic, 16.
  belting, 145.
  collection in Africa, 6, 15.
  goods, thin-walled, 64.
  printing on, 89.
  resins, 101.
  rollers, 147.
  shoes, 177.
    old, 225.
  stamps, 159.
  stamp ink, 161.
    sheet, 159.
  substance, 17.
  waste, floating, 220.
Running hose, 120.
"Rustling" of double waterproof, 85.

Salt solution, 174.
Salt-water tank, 174.
Sand-blast, 217.
Sapium, 7, 41.
Saponifiable oils, 118.
Seamless tubing, 139.
Seams, 2.
Sernamby, 9.
Shafting in washing-shop, 27.
Shaping machine, 145.
Sheet-cutting machine, 175.
Sheet-rubber, 141.
Shellac, 221.
  solution, 157.
Shellacing machine, 198.
Shoe-cap linings, 184.
Sieve, cylindrical, 45.
  revolving, 43.
Sieves, 43.
Silica, 216.
Singeing machine, 162.
Siringorana, 7.
Smoking rubber latex, 8.
Smooth surface of tubing, 140.
Soap solution, 176.
Soapy water, 214.
Sodium sulphite solution, 227.
Softening crude rubber, 23.
Soft-rubber articles, 120.
Solar oil, 211.
Sole calenders, 180.
Soles of galoshes, 179.
Sole-sheet, 180.
Solution brushes, 132.
  for hose, 126.
Solvents for chloride of sulphur, 81.
Specific gravity, 230.
Speed of mixing-rolls, 44.
  washing-rolls, 28.
Spiral hose, 128.
  spring, 128.
Spreading calenders, 56, 162, 170.
  knife, 167.
  machine, 162, 169.
  shop, 5, 162.
Spread sheet, 198.
Starch, 86, 90.
Steam banks, 70, 190.
  circulation, 70.
  -trap, 67.
Stearic acid, 119.
Steel cylinders, 174.
  mandrels, 129.
Stone-crusher, 204.
Stoppers, rubber, 135.
Storage of crude rubber, 23.
Stove for vulcanising galoshes, 187.
Stretching apparatus, hydraulic, 75.
Substitutes, 110.
  examination of, 114.
Sulphur-bath vulcanisation, 77.
Sulphur, chemically combined, 60.
Sulphur chloride, 80, 157.
Sulphur heater, 77.
Sulphuring up, 63.
Surface tension, 81.
Surgical rubber goods, 155.
Synantherea mexicana, 14.

Tables of analytical values, 19.
  ebonite vulcanisation results, 208, 209.
Tapping, 7.
Tapuru, 7.
Teats, vulcanisation of, 78.
Temperature equilibrium, 85.
  fall of, in cold-cure, 82.
Theoretical basis of mixing, 100, 178.
Thread-cutting machine, 199, 200.
  elastic, 196.
  -sheet, 197.
Tin, block, 213.
  -foil, 210.
  calenders, 213.
  drawing, 213.
  manufacture, 213.
Tin, haloid salts of, 90.
Toothed-wheel gearing (of calenders), 48.
Transparency of cold-cured waterproofing, 86.
Tripoli powder, 219.
Trolley, for galoshes, 187.
Tube-machine, 121, 126, 140, 141.
Tubular rings, 145.
Tyres, motor, 152.
  pneumatic, 150.

Union rubber, 195.
Uppers, 181.
Urceolo esculenta, 16.

Vacuum-drying, 38.
-hose, 120, 128.
Valves, 135, 143.
Varnishing galoshes, 185.
-machine, 172.
Vaseline, addition of, 118, 140.
Velvet rubber, 195.
Ventilation, 98.
Virgin Para, 10.
Vulcanisation, 20, 59.
centralisation of, 67.
coefficient, 61, 71, 225, 226.
cold, 59, 80.
plant for, 97-99
control of, 67.
degree of, 61, 78.
facilitation of, 63.
in hot-air, 85.
in sulphur-bath, 77, 79, 135.
in water-bath, 211.
of canvas hose, 131, 132.
of cut-sheet, 78, 97.
of galoshes, 187.
of insulated wire, 190.
of moulded goods, 135, 138.
of Para-sheet, 200.
of rollers, 149.
of tyres (pneumatic), 152.
of waterproof, 79, 87.
tables, 83, 84, 208, 209.
Vulcanised asbestos, 191.
Vulcanising ball-press, 138.
chamber for canvas hose, 134.
cone, 131.
heaters, 67.
Vulcanising heaters with rotating drum, 70, 190.
machine, 91, 95.
press, 71, 135.
roller, 88, 92.
shop, 5.
solution, 81, 87, 157.

Warp, 130.
Wash-hollander, 26, 29.
Washing, loss on, 32.
raw rubber, 23.
rolls, 24, 26, 28, 30.
shop, 27.
Waste rubber, 225.
floating, 220.
Water-bath vulcanisation, 211.
bottles, hot-, 155.
-cushions, 155.
-fastness of colours, 89.
hose, 125.
Waterproof fabrics, 84, 85.
printing on, 169.
Wax, addition of, 117.
Weft, 130.
Weighing-up mixings, 42.
Weight of moulded goods, 135.
Welt, 183.
Wet-press rollers, 147.
Winding apparatus, 47.
Wire, galvanised iron, 128.
insulated, 188.
Workshops, 1.
Wrapping, 121, 123.
cloths, 123.
machine, 124, 125, 142, 151.

Zinc chloride, 229.
compounds, 103.

INDEX OF NAMES.

Adolf. G.. 192,
Axelrod, Dr., 119.

Balla, 110.
Baur, Dr., 190, 198.
Borneo Rubber Co., 16.
Breuil, P., 63.

Clouth, F., 7, 12, 13, 61, 62.

Ditmar, Dr. R., 21.
Doughty, 178.

Esch, Dr. W.. 110.

Frankenburg, 89.

Gebauer, Fr., 31.
Goodyear, Charles, 59, 201.

Hancock, Thomas, 59, 201.
Harries, Dr. C., 17, 21.
Haubold, C. G., jun., 45, 174, 188, 193, 206, 211.
Heil, A., 70, 211.
Henriques, Dr., 12, 17, 19, 111.
Herbst, Edgar, 19.
Heywood and Bridge, 32.
Höhn, 113.

Kamerun Kautschuk Co., 16.

Macintosh, C., 173.
Marzoll, 231.
Meyer, L. Otto P., 201.
Minder, J., 84, 166, 169.

Parkes, A., 59.
Passburg, 38.

Shaw, F., 144.
Soskin, Dr , 19.

Theilgaard, 225.
Tilden, Prof., 21.
Tröster, 153.

Ule, E., 7, 12.

Weber, Dr. C. O., 61, 89.
Wildeman, E. de, 6, 7.

PRINTED IN GREAT BRITAIN BY NEILL AND CO., LTD., EDINBURGH

SOUTHEASTERN MASSACHUSETTS UNIVERSITY
3 2922 00314 835 7

Date Due

Date Loaned

12 [illegible] 953			
[illegible]			

SPECIAL COLL TS 1890 .H4
Heil, Adolf. 1919
The manufacture of rubber
goods